Münir Öztürk · Khalid Rehman Hakeem
I. Faridah-Hanum · Recep Efe *Editors*

Climate Change Impacts on High-Altitude Ecosystems

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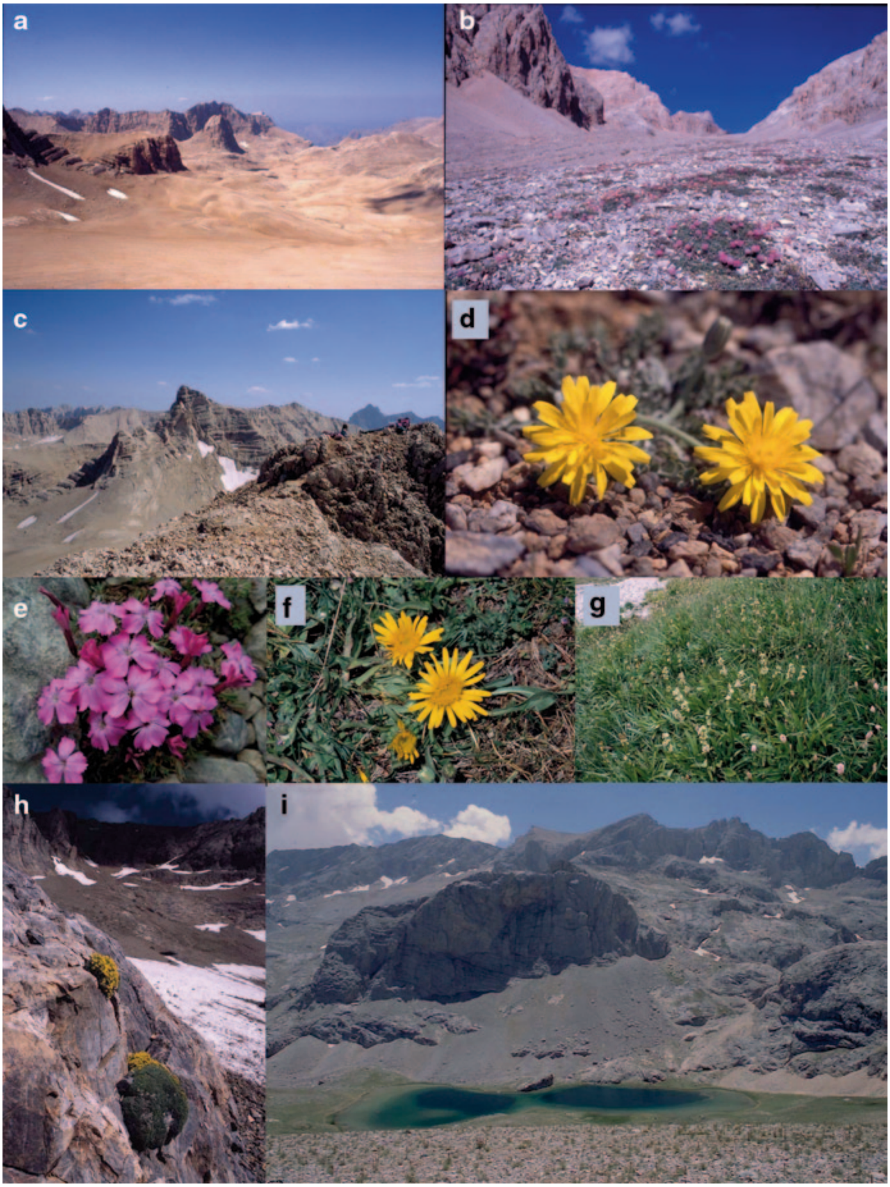
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Preface

The environment is constantly changing due to our unsustainable activities. The challenge we are facing currently is to predict how future agriculture will respond to the changing environment. A rise in global mean temperature will mean increase in the melting of mountain glaciers, the permafrost soil zone, and the polar ice caps, posing a common global threat. The climate change impacts on soil structure constitute a more complex process. The direct impact will be on the degradation of aggregates in the soil due to raindrops, surface runoff, and leaching, especially during heavy rains, thunderstorms, the increasing in flood frequencies which are the typical characteristics of climate change. The indirect influences will originate from the changes in the vegetation patterns and land-use practices.

The ecosystems are a part of the climate and living beings have adapted to their regional climate over time. However, our adhoc activities and degradative attitudes have lead us to a situation that more than 60 % of the species have shifted from their habitats and grow now as "refugee species." Infact, human created climate change will be one of the major threats of extinction to the biodiversity. Nearly 30 % of the species are face to face with a risk of extinction today. The habitat change is expected to result in the extinction of approximately 26 % of the species upto 2050. Atmospheric concentrations of carbon dioxide have been steadily rising, and projections are that in 2100 these may reach the levels ranging between 500–1000 ppm. These increases together with the changes in temperature; expected to reach to approximately 3 °C above the current values by 2100; will pose a serious threat to global crop production, change the geographical distribution and growing season of crops, and may reduce crop yields up to 17 %. Plants will face several types of injuries from temperature stress, eventually leading food insecurity.

Already these changes are affecting the high-altitude and high-latitude ecosystems. Their resilience will be affected greatly during the course of this century. The effects of regional climates on the plant diversity at high altitudes is revealing that there is shift in the distributional ranges of species, directly depicted by phenological changes, an early onset of flowering, migration, and lengthening of the growing seasons.

The temperature increase due to global climate change will bring significant alterations in the altitudinal patterns of high-altitude forests in particular alpine zones.

These will face a change in the important ecosystem processes including impacts on snow accumulation, melting of glaciers, and a decrease in the water resources. Any degradation of forest cover will mean facing avalanches, decrease in the reflectance of solar radiation, increase in soil erosion, flooding, and landslides. The timberline species will serve as a key for understanding altitudinal variations.

Objectives of this book are to present a comprehensive insight on the problems related to ecosystem fragmentation, health and well being of high altitude ecosystems, ecosystem services for food and medicine, and the situation of invasive alien species.

A total of 23 chapters have been included contributed by the eminent scientists of the subject from Turkey, Pakistan, South America, Malaysia, Nepal, Kirgizistan, Kazakistan, Georgia, Russia, Macedonia, Indonesia, and from North America.

We have more hotter and drier times ahead, many valuable ecosystems will be lost, there will be changes in the timing of seasonal life-cycle events, range shifts in many species, and threshold effects will be observed.

The data presented here covers some of the most important mountain ranges in the world including the Himalayas, Andes, Altai's, Tien-Shan, Caucasus, Taurus, Amanos, and other high altitude mountains of Turkey from the Black Sea region as well as Central and East Anatolian regions.

This work discusses the ecosystem health and climate change, ecosystem productivity, climate change and threats to high altitude ecosystems, soils and other limiting environmental factors at high altitudes. It also focuses on improving our understanding on the effects of climate change on biodiversity and is trying to give a thorough insight to the young researchers on these fragile ecosystems for their future evaluation.

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The idea for editing this volume took shape during the COMSTECH workshop held at Islamabad, Pakistan in September 2012. As such, special thanks are due to Prof. Dr. Qasim Jan Advisor COMSTECH as well as his hard working team for their support and encouragement. Prof. Jan inspired me (Münir Öztürk) greatly to work on this project.

The motivation I (Münir Öztürk) got from Prof. Dr. Ahmet Ruhi Mermut (Soil Sciences Department, Saskatchwan University-Canada and Harran University, Turkey), Prof. Dr. M. ASHRAF (Rector NS University of Agricultural Science, Multan, Pakistan); Prof. Dr. Khan Bahadar Marwat (Rector SBB University, Sheringel-Upper Dir, Pakistan), Prof. Dr. Zabta Khan Shinwari (Ex-Rector Kohat University, Pakistan), and the young participants at the workshop tremendously contributed to this project.

Apart from our efforts, the success of a project depends largely on the encouragement from many others like the Springer team who collaborated with us; therefore our greatest appreciation goes to them.

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Chapter 1
High-Altitude Flora and Vegetation of Kazakhstan and Climate Change Impacts

L. A. Dimeyeva, G. T. Sitpayeva, B. M. Sultanova, K. Ussen and A. F. Islamgulova

1.1 Introduction

The Republic of Kazakhstan (55°26′–40°56′ northern latitude and 46°27′–87°18′ eastern longitude) lies between Siberian Taiga and Central Asian deserts. In the direction from west to east, the country stretches as far as 3000 km, from north to south—1650 km. Its area makes up 2724.9 km^2. The Republic is situated in the center of the Eurasian continent. Such a deep continental location determines considerably its natural conditions. Steppes occupy more than a quarter of the country's area (Ozturk et al.1996a, b), deserts take up a half of the country, and the rest of the territory is occupied by mountains, lakes, and rivers. Plain territory is divided from north to south into forest steppe, steppe, and desert nature-climatic zones; eastern and south-eastern areas of the country present mountain ridges. The highest point is the Khan Tengri Mountain (6.995 m), located on the border with China and Kyrghyzstan.

On the basis of botanical-geographic regionalization, the country is located in two botanical-geographic regions: Eurasian steppe and Sahara–Gobi desert (Rachkovskaya 2006; National Atlas 2010). The steppe portions of Kazakhstan are associated with the Black Sea–Kazakhstan subregion of the Eurasian steppe region. It has three provinces: west Siberian forest steppe and Trans-Volga–Kazakhstan steppe in plains and south Altai in the mountains. Desert portions are associated with the Iran-Turan subregion of the Sahara–Gobi desert. North Turan, south Turan, and Junggar are provinces in plains; Junggar–north Tien Shan and Central Asian Mountains are highland provinces.

The flora in general includes almost 6000 vascular plant species, 14 % being endemics. On an average basis, 1000 km^2 of its area has two vascular plant species, the index ranging from 27 (Altai) up to 146 species (western Tien Shan) in the mountain regions. Latter occupy less than 9 % of the country's area but represent over 60 % of the plant species diversity of the country. Being floristic origin centers,

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mountainous ecosystems are characterized not only by maximum concentration of plant diversity but also by the maximum original and unique nature (National Strategy 2001) and include: the Altai, Saur, Tarbagatai, Junggar Alatau, Tien Shan (northern, western) Mountains. Different vegetation types on these habitats are preconditioned by integrated factors: zonal position of the plains that surround a mountainous system; ridge orientation; relative and absolute altitudes; climatic features; and plant cover history (Rachkovskaya et al. 2003). The lithology of rocks too is of great importance, as well as the combination of warmth and moisture and their fluctuations (climatic inversions) depending on their slope exposure and height.

In general studies on the belt, distribution of plants in the mountains is the first stage in the investigation of the mountain region vegetation structure. Altitudinal belt of the vegetation is an altitude interval in mountains that differ in its hydrothermal regime, with certain prevailing types of soils and regular combination of plant communities pertaining to one or several types of vegetation. Sub-belt is characterized with a certain structure of plant communities of the dominant vegetation type that grow on various soil subtypes (Vegetation of Kazakhstan and Middle Asia 1995). Changes of vegetation cover in sub-belts are assessed according to the structure of plant communities: a set of species life forms, composition of dominant species, interrelation of species, ecological groups (mesophytes, xerophytes, etc.), and ratio of phytocoenotic groups of species (meadowsteppe, steppe, shrub groups, etc.).

Altitudinal zonality reveals itself depending on the set of climatic, geological, and orographic features. Mountain vegetation of Kazakhstan is subdivided into four groups of altitudinal zonality types: the Altai group (in dry steppes), the Saur–Tarbagatai (in desert steppes), the Junggar–North Tien Shan (in moderate cold deserts), and the west Tien Shan group (in the southern moderate hot deserts) (Rachkovskaya 2006).

In this chapter, we will discuss the traits of the flora and vegetation, patterns of altitudinal zonality with examples from three mountain systems (Fig. 1.1): the Altai (the southern Altai ridges), the north Tien Shan (the Kyrghyz Alatau range), and the western Tien Shan (the Talass and Ugam ridges).

Fig. 1.1 Study areas

This study covering the current state of the plant cover, the traits of species and communities distribution in the mountain belts, the identification of floristic composition of the plant communities, and the typology of vegetation will allow us to reveal plant response to the climate change as well as to identify vulnerable species, predict possible ways of migration and dynamics of the mountain belts.

The research is based on the data received from the projects supported by Ministry of Education and Science of the Republic of Kazakhstan titled "Scientific Basis for Sustainable Use of Plant Cover and Plant Resources in the Southern Altai" (2006–2008) and "Botanical Diversity of Crop Wild Relatives in Kazakhstan as a Source for the Enrichment and Conservation of Agrobiological Diversity Genetic Fund for the Implementation of the Food Program" (2013–2015). Species names and plant family characteristics have been taken from Cherepanov (1995).

1.2 Natural Conditions

1.2.1 The Southern Altai

The southern Altai mountainous system is located at the junction of Kazakhstan's frontier with Russia, Mongolia, and China. The ridges are mostly of sub-latitudinal stretching (the southern Altai, Altai Tarbagatai, Sarymsakty, Narym, Kurshum, Azutau ridges), composed of metamorphic Cambro-Silurian, Silurian, and Devonian shale rocks. It is a mountainous system with folded dislocations that supposedly terminate at the Paleozoic and Mesozoic junction (Nikolaeva and Muzalevskaya 1978; Geldyeva and Egorova 1978).

1.2.2 Topography

The most typical relief forms are high-mountain alpine landscapes with abrupt steep slopes; leveled high-mountain—plateau-like uplands; erosive mid-mountain or mountain taiga; leveled mid-mountain accumulative and erosive valley; low-mountain erosive zone; accumulative and erosive low-mountain valley and valley-low mountain; erosive foothills; accumulative and erosive foothills; intermountainous accumulative and highly accumulative and erosive plains of large tectonic depressions; foothill base accumulative and erosive plains; piedmont declivous accumulative plains. The absolute altitudes of the region range from 600 to 700 m in the west and south-western foothills; and up to 4506 m above sea level (a.s.l.; the Belukha Mountain) in the north. The slopes are asymmetric: in the north they are short and steep; in the south—long and gentle. Intermountain depressions are frequent and mostly located in the lines of tectonic splits. The largest are the Markakol, Verkhnekabinskaya, Bobrovskaya, Orlovskaya, and Verkhne–Bukhtarminskaya depressions. The southern Altai Mountains are distinguished with gentle undulated plateau-like surfaces located at elevations of 1100–2000 m a.s.l.

1.2.3 Hydrography

The largest rivers are Bukhtarma, Kurchum, Kaljir, and Narym. All these rivers are characterized by comparatively narrow beds (about 2–5 ms), little depth (down to 1 or 3 m), and swift torrents. The main sources providing the recharging of rivers are melting snow and glaciers (40–70 %), the share of groundwaters in annual river discharge makes up 10–15 % (Boldyrev 1978). There are 1003 lakes in the region with total area of 528 km^2. Average availability of irregularly located lakes is 0.5 % (Filonets et al. 1978). For the most part, they are found in the northern and north-eastern part of the region, the largest ones being located in river valleys and intermountain depressions, like Markakol (area is 455 km^2), Bukhtarminskoye (4.23 km^2), and Ulmes (2.51 km^2). The recharging occurs at the account of precipitation as well as streams and rivulets.

1.2.4 Soils

There are two vertical oroclimatic levels of zonal soils in the southern Altai that correspond to the southern and northern slopes (Sokolov 1977). The common upper elements of the levels are primitive mountain tundra soils that develop under the influence of high-mountain xerothermic factors. On the lower slopes of the northern and (partly) eastern exposure, primary mountain tundra peat soils are distributed, as well as mountain taiga acid soils, mountain forest dark gray, sometimes chernozem-like soils; sparse mountain forest steppe and steppe chernozems. On the southern and western slopes, there are primitive mountain tundra peat soils or mountain meadow soils. They are followed in the lower slope direction by mountain peat forest meadow dark soils, mountain meadow steppe, and mountain steppe dark xerophilic soils. Mountain dark chestnut soils lie on the slopes of all expositions. Dark chestnut chernozem-like forest and steppe chernozems are wide spread in the intermountain depressions.

1.2.5 Climate

The southern Altai represents a zonal climatic boundary between dry steppe subzone and semidesert zone that concurs with the great axis of the Eurasian continent. The climate features are determined by altitudinal zonality and influence of northwest Atlantic humid winds that bring precipitation. Annual precipitation varies from 400 mm in foothills up to 800 or 1000 mm in mountain forest belt. The southern Altai is the coldest place in the Kazakstan Altai. Annual radiation balance value in the Markakol Lake is 22.1 $kcal/cm^3$ (Bolshenarymskoye village—33.9; Katon-Karagai village—28.0). Average annual air temperature (1446 m a.s.l.) is −4.5 °C. The ice in the lake starts melting in May. The hottest month is July (average temperature is +15.6 °C, the maximum reaches to +36 °C, and the minimum is +4 °C). Snow cover appears in late October or early November. Average depth of snow cover is

40–70 cm on sites without forest, up to 3 or 4 m in the upper parts of depressions. Snow cover lasts for 160 or 170 days. Average depth of soil freezing in the settlement of Katon-Karagai is 67 cm (from 47 down to 100 cm).

The average long-term climatic data have been taken from the meteorological station of Katon-Karagai located in the mountainous valley, at an elevation of 1081 m a.s.l. (Reference Book 2004; Research and applied Reference Book 1992). Average annual temperature is +1.5 °C; average annual precipitation is 450 mm; number of frost-free period in days is 111; average January temperature is −13.6 °C; average July temperature is 16.5 °C (Tables 1.1 and 1.2); the absolute minimum temperature was −44.4 °C (1951); the absolute maximum +35.7 °C (1983);and the sum of positive air temperature indices during the period with an average daily temperature above 10 °C is 1768.

1.3 The Kyrghyz Alatau Range

The Kyrghyz Alatau range is located latitudinally in the midst of the northern and western Tien Shan Mountains, extending between the Chu and Talass Rivers. The range belongs to the north Tien Shan. Its length is 360 km, width 30–40 km (Shlyghin 1971). The range is asymmetrical geomorphologically. Southern slope is steep, less dissected, while the northern one is more gentle and elongate. In this connection, the river valleys of the northern macro- slope are long and deep, while those of the southern one—steep and abrupt. The upper layer of the Kyrghyz Alatau represents a dissected rocky and glacier highland that in lower layers is sequentially replaced by mid- and low-mountain relief with a belt of ridged and crimpy foothills. The snow line runs at an elevation of 3200–3500 m a.s.l.

1.3.1 Topography

Only western part of the northern slope enters the territory of Kazakhstan with absolute altitudes up to 3700 m a.s.l. The slope is composed of metamorphic rocks and granites covered with sandstones, lime rocks, and the Carboniferous aggregations. Within its limits, the following types of relief are distinguished: high-mountain ridge

Table 1.1 Average monthly temperature (°C) at the meteorological station of Katon-Karagai from 1932 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−13.6	−12.2	−6.7	2.8	9.8	14.6	16.5	14.8	9.7	2.2	−7.6	−12.2

Table 1.2 Average monthly precipitation (mm) at the meteorological station of Katon-Karagai from 1932 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
14	13	15	30	60	62	65	56	42	40	31	22

relief (3000–3700 m) with the modern glaciers, mid-mountain relief (2200–3000 m), low-mountain relief intermittent with foothills and valleys (1000–2200 m; The Relief of Kazakhstan 1991). The high-mountain relief with the modern glaciations is typical of the dividing part of the range. In its extreme south-eastern part (within Kazakhstan), leveling surfaces are covered with the modern glaciers. There are traces preserved from the two old glaciations—mid-quaternary semi covered and upper valley quaternary glaciations in the form of moraine outliers, relicts of glacier trough valleys, circuses, and cirques. The mid-mountain ridge relief occupies a wide zone. Slopes of river valleys are steep and abrupt. The valleys have an aspect of gorges and canyons. Low-mountain relief parts from the mid-mountain one by clear-cut ledges, with an average dissection depth of 300 m, representing turf-covered gentle slopes. Upstream valleys are V-formed, well developed, with a narrow floodplain and fragments of the first and second river terraces above floodplain. Foothills represent trails of sediment cores involved in elevations and dissected into separate beds and ridges.

1.3.2 Hydrography

The region's large rivers are Chu, Talass, Kuragaty, and Assa. The Chu River is formed from confluence of two mountain streams: Karakhojur and Kochkur that recharge from melting snow and glaciers (Assing et al. 1967). Most notable mountain streams falling into the Chu River are the Greater Kemin, Merke, Aspara, and Karakistak. The Talass River is formed from confluence of two streams: Karakhola and Ush-Koshoma. The Talass River's upper course is of a mixed snow and ice recharging with a rapid flow.

1.3.3 Soils

The following soils are distinguished on the Kyrghyz Alatau northern macro-slope (Assing et al. 1967; Mamytov 1987): (1) gray soils (650–1000 m), (2) light chestnut soils (700–1100 m), (3) dark chestnut soils (1100–1300 m), (4) mountain dark chestnut soils (1400–1500 m), (5) mountain chernozems (1500–2200 m), (6) high-mountain meadow subalpine soils (2200–3000 m), (7) high-mountain forest soils (2500–3000 m), and (8) high-mountain meadow peat and semi-peat alpine soils (3000–3500 m). There is no mountain chernozem and high-mountain forest soils zone in the western part of the range (Durasov and Tazabekov 1981). Rocks and stones occupy large areas on the mountain slopes.

1.3.4 Climate

A typical feature of the Kyrghyz Alatau climate is harsh continentality and aridity in foothills. The amount of precipitation grows, moving from west to east. In the lower parts of the range, spring, winter, and autumn precipitations prevail, summers are hot and dry. In the higher parts of the range (at an elevation above 1600 m), precipitation patterns are equable, rain falls in summer as well. In the western extremity of the Kyrghyz Alatau Mountains, summers are dry with temperatures up to +30 °C or +35 °C. Winters are cold, with little snow and temperatures of January and February go down to −25 °C. The climatic conditions are not the same at various altitudes. As the elevation grows, temperature changes from hot zone to cold one with larger annual amount of precipitation reaching 500 mm and over (Serpikov et al. 1965). Annual precipitation in the foothills varies between 200 and 300 mm. The maximum precipitation falls in spring and early summer. The climatic conditions of numerous transverse valleys depend on expositions of slopes and available orographical features. Winters of the narrow meridional valleys are colder, last for more than 4 months, while those of lower parts of valleys—three and a half months. Summers are hot only in lower parts of the valleys, in other places moderately warm. Precipitation patterns are irregular, depending on altitude and slope exposition, its amount fluctuates from 290 or 300 to 400 or 500 mm (Puzyryova 1975).

Average annual climate data have been taken from the meteorological station of Merke town located in foothill plain, at an elevation of 690 m a.s.l. (Reference Book on Climate of Kazakhstan 2004a; Research and applied Reference Book 1992). Average annual air temperature is 9.9 °C; average annual precipitation 411 mm; number of frost-free days is 171; average temperature in January is −5.1 °C; that in July is +24.7°C (Tables 1.3 and 1.4); the absolute minimum temperature was—36 °C (1951); the absolute maximum was +44 °C (1997); and the sum of positive air temperature indices during the period with an average daily temperature above 10 °C is 3622.

1.4 The Western Tien Shan Mountains

The western Tien Shan part in Kazakhstan belongs to the western extremity of the Talass Alatau range which extends westward in the form of two long mountain ranges—one in north-western direction called Jabagly and the other in south-western direction under the name of the Ugam–Karzhantau Mountains (altitude 4200 m a.s.l.). There are also smaller mountains—Kazygurt, Alatau, and the Syr Darya Karatau range. All are composed by Paleozoic solid rocks (mostly with Carboniferous marine calcareous sediments). The mountain ridges are stretched, horseshoe formed. The front sides of the mountains look out on to west, length being

Table 1.3 Average monthly air temperature (°C) in the meteorological station of Merke from 1936 to 1958 and from 1966 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−5.1	−3.6	3.1	11.5	16.8	21.7	24.7	22.8	17.3	10.0	2.1	−3.1

Table 1.4 Average monthly precipitation amount (mm) in the meteorological station of Merke from 1936 to 1958 and from 1966 to 2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
24	30	52	66	56	36	17	12	14	39	38	27

120 km, width 30 km in the east, and 45 km in the west. The eastern extremity of the "horseshoe" at the extension of 25 km westwards represents entirely highlands (Karmysheva 1982).

1.4.1 Topography

High ridges of the mostly elevated parts are characterized by high-mountain alpine relief with prevailing steep and highly steep slopes, cliffs, and stony screes. The pre-glacier layer is located at 3400–3800 m a.s.l. There is a high-mountain alpine relief with steep slopes and rare sites of the old leveling in the dividing part of some ridges. As the altitudes lessen, the relief is replaced by high-mountain leveled one, distinguished for the prevailing slightly dissected planoconvex watersheds with gentle, slightly steep and steep slopes. The upper part of the high-mountain belt bears traces of the old and modern glaciations, and the lower parts reveal traces of the old glaciation only (relic troughs, cirques, moraines), as well as the modern glaciations in the form of summer-melting snowfields. As a rule, the high-mountain relief is replaced by mid-mountain one within the altitudes of 1400–2300 m, with prevailing steep and highly steep slopes. The mid-mountain belt is replaced by low-mountain one where slopes are less steep. However, near streams and rivers, steep and highly steep slopes and sometimes cliffs (in canyons) prevail. Low mountains and ridges are distinguished for more leveled relief with gentle slopes. On the contrary, their northern and north-eastern slopes are characterized by steep slope with highly dissected relief (Zhikhareva et al. 1969).

1.4.2 Hydrography

The Talass Alatau forms a mighty mountainous assembly on the frontier with Kyrghyzstan with considerable glaciation fields where from numerous streams take their origin and flow in various directions. The most important are Maydantal and Oygain which flow south-westward; Kurkureusu, Koksay, and Aksay run northward; and Jabagly and Aksu westwards. Although the streams are torrential, the water is distributed unequally. The uppermost regions of the mountains and their southern slopes are almost waterless. The northern slopes, on the contrary, are flooded abundantly, together with the large and small valleys in northern and north-western directions between 1300 and 3000 m (Galitskiy 1968). Some of the streams (Aksu, Koksay, Mashat, Daubaba, Irsu) after leaving the mountains, run on the bed of deep canyons. The Sayramsu, Chunkuldek, and Baldybrek streams are the most easily accessible water sources.

1.4.3 Soils

In the high mountains around the pre-glacier level, there is almost no soil. The high-mountain soil cover is mostly represented by mountain alpine meadow and steppe (or high-mountain meadow and steppe), primitive or accidentally by normal shallow soils. Of less distribution is mountain steppe alpine (or high-mountain steppe) soils that form on less humid slopes. Mountain meadow alpine hydromorphic soils are still less here. They develop in negative relief elements under conditions of additional surface moistening (snowfields) and ground moistening below low-grassy meadows ("sazy").

Brown mountain shingly gravel soils are typical of high-mountain meadow steppes. The mid-mountain soils pertain to brown soil type with gravel and large amount of broken stone (especially on the southern slopes). The gray-brown mountain soils of the steep and gentle slopes in southern and western expositions are covered by shrubby tallgrass savannoids. Low mountains are distinguished with chestnut or brown soils (in the belt of trees and shrubs) that have a larger humus horizon in comparison with silt soils (Ghirkina 1965).

1.4.4 Climate

The climate is typical of Central Asian Mountain, where summers are hot and dry, with air temperature up to +30 °C in mid-mountains and up to 39 or +40 °C in foothills and piedmont plains. Winters are snowy, though not long, are cold with frosts down to −30 to −35 °C. On the northern slopes of mid-mountain in juniper forest belt, the height of snow cover is around 1.4–1.6 m. The snow is easily blown off in places unprotected from the winds. Frost may be observed in the alpine belt even in early July, and then, beginning from the second half of August (Bulavkin et al. 1971). Average annual precipitation for mid-mountain zone is about 700 mm, for high mountain—about 1000 mm. According to the seasons, precipitation is distributed as follows: winter—28 %, spring—38 %, summer—9 %, autumn—25 %.

Average long-term climate data were taken from the meteorological station of Tasaryk (Blinkovo) village which is located in the mountain valley at an elevation of 1122 m a.s.l. (Reference Book 2004b; Research and applied Reference Book 1992). Average annual air temperature is +9.6 °C; average annual precipitation 707 mm; the number of frost-free days is 185; average temperature in January is −3.1 °C; in July is +22.3 °C (Table 1.5 and 1.6); the absolute minimum temperature was −2.8 °C (1951); and the absolute maximum temperature was 40 °C (1983).

Table 1.5 Average monthly temperature (°C) at the meteorological station of Tasaryk in 1936–2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
−3.1	−1.5	3.1	10.3	15.1	19.7	22.3	21.3	16.1	9.6	3.5	−0.8

Table 1.6 Average monthly precipitation (mm) at the meteorological station of Tasaryk in 1936–2000

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
64	69	102	114	83	29	17	9	15	59	72	74

1.5 Flora, Vegetation, and Altitudinal Zonality

1.5.1 The Southern Altai

The southern Altai flora comprises 2091 species belonging to 604 genera and 119 families (Isayev 1993; Baytulin and Kotukhov 2011), which makes up approximately 40 % of the whole flora of Kazakhstan. The richness of flora on the southern Altai is due to its location in the center of the continent and hearth of Asian flora formation, and the region's highly diverse ecological conditions. Major families are: Asteraceae—299 species (14.3 %), Poaceae—281 (13.4 %), Fabaceae—170 (8.1 %), Brassicaceae—121 (5.8 %), Rosaceae—106 (5.1 %), Ranunculaceae—96 (4.6 %), Cyperaceae—80 (3.8 %), Caryophyllaceae—72 (3.4 %), Lamiaceae—72 (3.4 %), Scrophulariaceae—71 (3.4 %). The first 20 families make up 61.9 % of the whole flora. The main genera are *Astragalus*—66, *Carex*—53, *Salix*—42, *Artemisia*—37, *Allium*—35, *Oxytropis, Potentilla* -32, *Elymus*—28, *Poa*—27, *Ranunculus, Saussurea, Stipa*—25, *Veronica*—21, *Festuca*—19, *Viola*—19, *Pedicularis*—18, *Alchemilla, Juncus*—17, *Calamagrostis*—16, *Draba, Euphorbia*—15 species.

The number of plants on the high-mountain of the southern Altai lies around 374 species (17.9 %). Main families are Asteraceae—58 species (18.5 %), Poaceae—38 (10.2 %), Ranunculaceae—21 (5.6 %), Cyperaceae—19 (5.1 %), Brassicaceae—18 (4.8 %), Rosaceae—17 (4.5 %), Scrophulariaceae—16 (4.3 %), Fabaceae—15 (4.0 %), Caryophyllaceae—14 (3.7 %), Salicaceae—12 (3.2 %).

Endemic plants (68 species) demonstrate the unique features of the Altai flora: *Allium ledebourianum* Schult. et Schult., *Arenaria potaninii* Schischk., *Corallorrhiza trifida* Chatel., *Dactylis altaica* Bess., *Echinops saissanicus* (B. Keller) Bobr., *Elymus longespicatus* Kotuch., *Festuca kurtschumica* E. Alexeev., *Papaver tenellum* Tolm., *Pulsatilla patens* (L.) Mill., *Stemmacantha carthamoides* (Will.) M. Dittrich, *Rhodiola quadrifid*a (Pall.) Fisch.et Mey, *Trollius altaicus* C. A. Mey, *Tulipa altaica* Pall ex Spreng., etc. The abundance of endemic plants in the southern Altai is determined by intensive migration of species. An intensive hybridization of genus *Elymus* is observed at both species and generic levels in common habitats of mountain-steppe and mountain-siberian species, affected by severe environmental conditions (sharp continental climate, summer rainfall abundance, the presence of the modern glaciation, high insolation, and frequent negative temperatures in vegetative period). Intergeneric hybrids (x *Elymotrigia* Hyl) arise usually with *Elytrigia* (*E. gmelinii, E. repens, E. geniculata*, etc.; Kotukhov 1990).

From among the 73 rare plant species of the southern Altai, 27 are included in the Red List of Kazakhstan (The List of Rare and Threatened Plant species 2006): *Adonis vernalis L., Allium altaicum Pall., A. ledebourianum Schult. et Schult. fil., A. microdictyon Prokh., Arnica iljinii (Maguire) Iljin, Corydalis bracteata (Steph.) Pers., Cypripedium guttatum Sw., Dactylorhiza longifolia (L. Neum.) Aver., D. fuchsii (Druce) Soo, D. incarnata (L.) Soo, Epipogium aphyllum (F. W.Schmidt) Sw., Erythronium sibiricum (Fisch. et C. A. Mey.) Kryl., Gymnospermium altaicum (Pall.) Spach, Huperzia selago (L.) Bernh. et Schrank et C. Mart., Lilium pilosiusculum*

(Freyn) Miscz., Macropodium nivale (Pall.) R. Br., Paeonia anomala L., P. hybrida Pall., Paris quadrifolia L., Pulsatilla patens (L.) Mill., Rheum compactum L., Rhodiola rosea L., Sanicula europaea L., Sibiraea laevigata (L.) Maxim., Stipa pennata L., Tulipa patens Agardh ex Schult. et Schult. fil., T. uniflora (L.) Bess. ex Baker.

There are 98 wild relatives of crop species in the region, mostly belonging to the families of Fabaceae, Rosaceae, Alliaceae, Asteraceae (*Hordeum brevisubulatum, H. bogdanii, H. turkestanicum, Allium caeruleum, A. decipiens, A. flavidum, A. altaicum*, *Amygdalus ledebouriana, Fragaria vesca, F. viridis, Rosa majalis, R. acicularis, R. caesius, R. idaeus, R. saxatilis, Crataegus chlorocarpa, Glycyrrhiza uralensis, Medicago lupulina, M. falcata, Onobrychis arenaria, O. arvensis Vicia megalotropis, V. tetrasperma, Lactuca altaica, L. tatarica, L. undulata*, etc).

The following altitudinal belts are identified in the southern Altai ridges: desert steppe, dry steppe, meadow steppe, mountain shrub meadow steppe, mountain forest steppe, mountain taiga, subalpine, alpine tundra, and high-mountain nival belts (Dimeyeva et al. 2012).

1.5.2 Desert-Steppe belt (400–600 to 800 m a.s.l.)

Sagebrush–feathergrass–fescue and sagebrush–festcue desert steppes extend to foothills and foothill plains of southern slopes. The plant cover is dominated by bunch grasses: (*Stipa sareptana, Festuca valesiaca, Koeleria cristata*), sagebrushes (*Artemisia gracilescens, A. compacta, A. frigida*), dwarf shrubs and dwarf semishrubs (*Kochia prostrata, Ephedra distachya, Thymus marschallianus*), shrubs are also frequent (*Caragana pumila, C. camilli-schneideri, C. frutex, Spiraea hypericifolia*), including desert ones (*Krascheninnikovia ceratoides, Atraphaxis spinosa, Halimodendron halodendron*).

1.5.3 Dry Steppe Belt (400–700 or 800–1200 m a.s.l.)

Dry steppe belt (400–700 or 800–1200 m a.s.l.) is typical of piedmont gentle slope plains of southern exposure. The plant cover is composed of dry steppes of feathergrass–fescue communities with shrubs (*Festuca valesiaca, Stipa capillata, Stipa lessingiana, Spiraea hypericifolia, Caragana frutex*) and abundant forbs (*Jurinea multiflrora, Galium ruthenicum, Iris scariosa, Dianthus rigidus, Potentilla acaulis, Potentilla bifurca, Galatella tatarica, Artemisia frigida, Artemisia marschalliana*).

1.5.4 Meadow-Steppe belt (900–1500 m a.s.l.)

The plant cover is dominated by bunch grasses (*Stipa lessingiana, S. krylovii, Festuca valesiaca, Helictotrichon altaicum*) and meadow grasses (*Dactylis glomerata, Alopecurus pratensis, Poa sibirica, Calamagrostis langsdorffii*). Among forbs are

Achillea nobilis, Galium verum, Pulsatilla multifida, Ziziphora clinopodioides and broad-leaved species: *Heracleum dissectum, Veratrum lobelianum, Aconitum leucostomum, Angelica decurrens, Delphinium elatum*. At the upper highland sites, genuine forb-grass upland meadows are observed (*Poa pratensis, Carum carvi, Rhinanthus glacialis, Euphrasia hirtella, Taraxacum* spp., *Plantago* spp., *Lamium album, Geranium affine, Rumex confertus, Urtica dioica*). The sediment cores are dominated by steppe meadows with another set of prevailing grasses (*Phleum phleoides, Helictotrichon pubescens, Poa angustifolia*) and forbs (*Tragopogon orientalis, Bupleurum longifolium, Iris ruthenica, Ligularia glauca, Tanacetum achilleifolium*). In combination with these occur shrubby meadow steppes. The shrub layer consists of *Rosa pimpinellifolia, Lonicera tatarica, Spiraea media, S. chamaedrifolia, Cotoneaster melanocarpa*; herbs are dominated by *Phleum phleoides, Helictotrichon pubescens, H. altaicum, Poa angustifolia, Dactylis glomerata, Clematis integrifolia, Pulsatilla patens, Lupinaster pentaphyllus, Lathyrus humilis, L. transsylvanicus, L. gmelinii*. They are frequently mixed with secondary origin shrubby grooves of *Spiraea media, Rosa pimpinellifolia, R. acicularis, Cotoneaster melanocarpus, Rubus idaeus*.

1.5.5 Mountain Shrub Meadow-Steppe Belt (1200–1500 m or 1800 m a.s.l.)

Mountain shrub meadow-steppe belt (1200–1500 m or 1800 m a.s.l.) is located on southern, south-eastern, north-western, and north-eastern slopes, where humid tall-herb meadows are widespread (*Calamagrostis langsdorffii, Milium effusum, Dactylis glomerata, Veratrum lobelianum, Chamaenerium angustifolium*) in combination with shrubby thickets (*Spiraea chamaedrifolia, Lonicera altaica, Ribesatro purpureum, Rubus idaeus*), as well as moderate-humid shrub-like xeropetrphytic steppes with prevailing petrophytic species (*Cleistogenes squarrosa, Centaurea sibirica, Orostachys spinosa, Aster alpinus, Sedum hybridum, Thymus altaicus*) and thickets of steppe bushes.

1.5.6 Mountain Forest-Steppe Belt (1500–1900 m a.s.l.)

Mountain forest-steppe belt (1500–1900 m a.s.l.) is formed at the lower border of forest. For the most part, it consists of larches that grow on gentle and medium steep slopes of northern and north-eastern exposure, sometimes on north-western or western exposure. Timber stands of *Larix sibirica* are pure, with little presence of *Betula pendula* in young stands. Among the underwood we come across *Lonicera altaica, Spiraea chamaedrifolia, Ribes atropurpureum, Rubus idaeus, Rosa pimpinellifolia, Rosa acicularis, Cotoneaster melanocarpa*. Herb layer is well developed, with prevailing grasses of *Calamagrostis epigeios, C. langsdorffii, Dactylis glomerata, Alopecurus pratensis*; from forbs *Polemonium caeruleum,* *Galium verum, Lathyrus pisiformis, Vicia cracca, Alchemilla xanthochlora, Carex pediformis*, *Aconitum leucostomum, Chamaenerium angustifolium, Paeonia anomala, Galium boreale* are common.

On southern slopes, stony meadow shrub steppes are found. The shrubby layer is represented by *Spiraea media, Cotoneaster melanocarpus, C. uniflorus, Rosa pimpinellifolia, R. acicularis*. In the herb layer, *Phleum phleoides, Helictotrichon pubescens, Poa angustifolia, Festuca krylovii, Stipa pennata, Carex pediformis, Veronica spicata, Dracocephalum nutans* are observed. Stony habitats are dominated by *Corydalis nobilis, Rheum compactum, Aconogonon alpinum,* while sites with gravel chippings are covered by *Ziziphora clinopodioides, Scutellaria supina, Allium nutans*.

Birch-aspen (*Populus tremula, Betula pendula*) forests are widespread. Aspen stands with forbs are formed on burnt out and slashed sites. Underwood consists of *Spiraea media, Rosa pimpinellifolia.* Herbage is dominated by *Dactylis glomerata, Calamagrostis epigeios, Geranium albiflorum, Veratrum lobelianum.* Aspen stands with large herbs are located on south-eastern slopes of high steepness; they are frequent on rocky places, where vegetation begins to appear. Underwood consists of *Lonicera altaica, Spiraea media, Ribes altissimum*. In herbage, tall plants are present: *Heracleum dissectum*, *Aconitum septentrionale*, *Urtica dioica, Dactylis glomerata, Calamagrostis epigeios*. Moss cover is absent.

Floodplains are dominated by gallery poplar forests (*Populus laurifolia*) with forb-grass layer, sometimes mixed with larch, birch, and willows. In underwood, *Ribes nigrum, R. atropurpureum, Lonicera altaica* are found.

1.5.7 Mountain Taiga Belt (1550 or 1900–2100 m a.s.l.)

Mountain taiga belt (1550 or 1900–2100 m a.s.l.) is typical of northern and north-western slopes. Three altitudinal sub-belts are distinguished there.

1.5.8 Lower Altitudinal Sub-Belt

Lower altitudinal sub-belt with birch-larch forests (*Larix sibirica, Betula pendula*) participated by *Abies sibirica*. The undergrowth is formed by *Lonicera altaica, Rosa acicularis, Ribes atropurpureum, Rubus idaeus, Sorbus sibirica*. The herbacous layer is dominated by *Calamagrostis epigeios, C. langsdorffii, Dactylis glomerata, Angelica decurrens, Paeonia anomala*; forbs are represented by *Rubus saxatilis, Crepis lyrata, Galium boreale, Saussurea controversa, Iris ruthenica, Geranium albiflorum*. Shrubby larch stands mixed with birches and fir trees are also found. Underwood is highly dense with *Spiraea media, Rosa acicularis, Lonicera altaica*. Herbs are composed of mesophylous grasses: *Calamagrostis epigeios, Aconitum leucostomum, Cerastium pauciflorum*. Moss cover is absent.

1.5.9 Middle Altitudinal Sub-belt

Middle altitudinal sub-belt is covered by larch and dark-coniferous forests. There are forbs, abies (*Abies sibirica*), moss larch forests. The underwood in forb larch communities is absent or rare (*Ribes atropurpureum, Spiraea media*). The herbs are multilayered and dense. Upper sites are dominated by *Dactylis glomerata*; in hollows mesophyllous species are found: *Aconitum septentrionale, Thalictrum simplex, T. minus, Heracleum sibiricum, Angelica decurrens*, *Paeonia anomala*. Mixed abies—larch forests with mosses are widespread in the lower part of northern slopes. The herb and moss cover is dominated by *Lycopodium annotinum, Pyrola rotundifolia, Linnaea borealis, Moneses uniflora.* Spruces (*Picea obovata*) occur on the slopes of eastern exposition. *Lonicera altaica, Spiraea media, Cotoneaster melanocarpa, Ribes atropurpureum* are widespread in shrubby layer. *Deschampsia cespitosa, Geranium pseudosibiricum, Chamaenerium angustifolium, Helictotrichon hookeri* are abundant in herb layer. Fir and birch (anthropogenic) forests are found in several places. Taiga with *Abies sibirica* occurs in the middle belt of the southern macro-slope of the Kurshum ridge, at an elevation of 1600–1700 m. *Abies sibirica* stands are pure, with occasional trees of *Betula pendula, Larix sibirica*. The underwood is sparse and consists of *Lonicera altaica, Sorbus sibirica*. Herbaceous cover is dominated by *Vaccinium myrtillus, Calamagrostis* spp, *Saussurea frolowii, Phlomoides alpina.* Moist dark coniferous forests consist of abies, singular trees of spruce (*Picea obovata*), Siberian cedar (*Pinus sibirica*), larch, birch. They are met in the middle part of northern slopes up to 1600 m. The underwood is composed of *Sorbus sibirica, Ribes altissimum, Lonicera altaica, Rubus idaeus.* Herbaceous cover of middle density is made up from *Carex* spp*, Saussurea frolowii, Pedicularis proboscidea*, in hollows we find *Calamagrostis* spp. Moss cover is well developed.

Pinus sibirica forests are located on the lower parts of slopes at an elevation of 1500–1700 m. In the shrub layer, *Lonicera altaica, Ribes atropurpureum* occur, and in the herbaceous layer *Calamagrostis langsdorffii, Carex macroura, Aconitum leucostomum, A. decipiens* are widespread. Cedar forests of *Vaccinium myrtillus* occupy the middle parts of slopes at an elevation of 1700–2000 m. Shrubby layer is sparse (*Lonicera altaica, Spirarea chamaedrifolia*). In herbaceous layer, *Linnaea borealis, Aconitum decipiens* are present, with widespread mosses (*Hylocomium proliferi, Pleurosium schreberi*).

1.5.10 Upper Altitudinal Sub-Belt

Upper altitudinal sub-belt corresponds to the upper border of forest (1800–2400 m a.s.l.) The vegetation is represented by larch woodlands with fragments of steppe alpine meadows (*Festuca valesiaca, F. kryloviana, Helictotrichon schellianum*). Underwood composition includes *Spiraea media, Juniperus sibirica, Cotoneaster uniflorus.* Steppe species prevail in the herbage: *Festuca valesiaca, Iris ruthenica, I. bloudowii*. Birch-and-blueberry-larch stands as well as birch–cedar woodlands are mixed with the mountainous and tundra vegetation.

1.5.11 Subalpine Belt (1800–2200 m a.s.l.)

Subalpine belt (1800–2200 m a.s.l.) comprises communities of the upper forest border. These are meadow and subalpine forest communities with two sub-belts.

1.5.12 Sub-Belt of Subalpine Meadows

The conditions are characterized by sufficient moistening due to late melting of snow cover, vapor condensation, and large rainfall in summer. Tall-herb subalpine meadows are expressed on the northern slopes. In the lower part of subalpine belt, they alternate with tall-herb-larch stands; in the upper micro-slopes of northern exposure—with subalpine larch communities. They have similar type of vegetation as in forest tall-herb meadows. However, they are characterized with an original species composition and genesis representing a primary formation, related to the upper forest border, while forest meadows result from fires and forest degradation as in the Mediterranean (Ozturk et al. 2010a, b). Grass composition is poor: *Calamagrostis* spp, *Poa sibirica, Alopecurus alpinus.* Moss cover is either absent or poorly developed. The herbage includes 64 % of forest species which are present in layer I: *Stemmacantha carthamoides*, *Saussurea frolowii*, *Trollius altaicus, Geranium albiflorum, Bupleurum longifolium, Delphinium elatum, Aconitum septentrionale*, *Hedysarum austrosibiricum, Veratrum lobelianum*; and 50 % of arcto-alpine species which are present in layer II: *Dracocephalum grandiflorum, Phlomoides alpina, Aquilegia glandulosa, Omalotheca norvegica.*

Low-herb subalpine meadows are formed as a result of exceeding grazing and consist of *Ptarmica ledebourii, Tanacetum achilleifolium*, *Delphinium elatum, Aconitum leucostomum*. The degradation is accompanied by the disappearance of palatable species and plants trampled by cattle, with enhanced role of rosette forms as in the high altitudes of east Mediterranean (Ozturk et al. 2008). Dominants are *Alchemilla sibirica, Geranium albiflorum, Sanguisorba alpina, Saussurea frolowii.*

1.5.13 Sub-Belt with Dominating Dwarf Shrubs

Betula rotundifolia thickets develop under the cover of subalpine forest communities. At the border with alpine tundra belt, the species form combinations with tundra communities (fragmented complex of alpine meadows, moss and lichen tundras). Prostrate juniper thickets (*Juniperus sibirica, J. pseudosabina*) occupy the southern slopes.

In the place of glacier moraine lakes, high-mountain swamps develop. Water sites are dominated by *Carex* species, *Eriophorum polystachion* flourishes on dry habitats, hills and hummocks are covered with moss. Community composition includes dwarf shrubs (*Salix* spp, *Betula rotundifolia*). Among alpine herbage, *Allium ledebourianum, A. schoenoprasum, Pedicularis compacta, Swertia obtusa* are present.

In the upper course of streams, subalpine willow communities occur (*Salix glauca, S. krylovii, S. vestita*). Herbage is composed by *Aconitum altaicum, Swertia obtusa, Angelica decurrens,* but *Rhodiola rosea, Allium altaicum* cover the rocks.

1.5.14 Alpine Tundra Belt (2000–2500 m a.s.l.)

There is not a clear floristic and phytocoenotical difference between alpine tundra and alpine meadows. Sparseness of plant cover as well as moss and lichen development is taken as a criterion for distinguishing grassy tundras from alpine meadows. There are frequent species that occasionally penetrate the alpine tundra zone from the lower mountainous belts: *Caltha palustris, Angelica decurrens*. The elevated relief elements of the lower part of the belt are represented by low-herb alpine meadows dominated by the following species: *Viola altaica, Bistorta major, Lloydia serotina, Gentiana grandiflora, Schulzia crinita, Aquilegia glandulosa*. Grasses are few: *Festuca kryloviana, Anthoxantum odoratum, Festuca altaica.* Prostrate dwarf willows are present: *Salix turczaninowii.* Moss cover is usually developed. Sedge-grass tundras are mostly distributed on is 25–30 %. *Festuca kryloviana* is dominant, and *Trisetum spicatum, Anthoxanthum odoratum, Carex melanocarpa, Lusula sibirica, Poa alpina* are the codominants. Forbs include *Tripleurospermum ambiguum, Potentilla evestita, Dracocephalum grandiflorum*. Meadow tundras with *Kobresia myosuroides* are found rarely on the northern slopes. Small abundance of *Festuca kryloviana,* and *Rhodiola quadrifida* is noted.

Alpine low-herb meadows with *Ranunculus altaicus, R. rubrocalyx, Potentilla evestita, Pedicularis amoena* tend to grow in depressions with lately melting snowfield spots (late July to early August). In gravel habitats, lichen tundras (*Cladonia, Cetraria*) are observed. On slopes, near groundwater outcomes, high-mountain moss swamps are spread (*Minium, Bryum, Sphagnum* spp.). Herb layer is dominated by *Carex* spp, *Eriophorum angustifolium, Allium schoenoprasum.*

Tundras with low ecoform of *Betula rotundifolia* and alpine willow species (*Salix glauca, S. turczaninowii, S. vestita*) are found rarely. Gravel and rocky tundras occupy highly gravel soils on the southern slopes of ridges. The herbaceous cover is not closed. Among grasses dominants are *Festuca kryloviana, Poa altaica, Trisetum spicatum.* Forbs include *Bistorta major, Callianthemum angustifolium, Rhodiola quadrifida, Potentilla gelida, Eritrichium villosum, Papaver nudicaule*, *Huperzia selago*, *Patrinia sibirica, Leiospora exscapa.*

Tundras with *Dryas oxyodontha* are occasional and tend to gentle gravel permafrost slopes.

1.5.15 High-Mountain Nival Belt (above 2800 m a.s.l.)

Higher plants are absent. Only some lichen species occur on the rocky outcrops.

The spatial distribution of plant cover in the southern Altai follows the altitudinal zonation pattern, and an asymmetry is clearly expressed by the plant cover on slopes of northern and southern exposure with prevailing forest and forest-steppe communities. The slopes of intermediate exposure are distinguished with rich diversity; mosaic distribution of plants is typical of herbaceous communities.

According to the ecological-physiognomic classification, six vegetation types are found in the southern Altai: arboreal, shrubby, steppe, meadow, swamp, and tundra vegetation (Table 1.7).

1.5.16 The Kyrghyz Alatau Range

The flora of Kyrghyz Alatau, within the area of Kazakhstan, is represented by over 850 species of vascular plants belonging to 345 genera from 74 families (Aralbay et al. 2007). The dominant families are Asteraceae—128 (15%), Fabaceae—76 (9%), Poaceae—59 (7%), Caryophyllaceae—47 (5.6%), Ranunculaceae—47 (5.6%), Brassicaceae—41 (5%), Rosaceae—40 (4.7%), Lamiaceae—36 (4%), Scrophulariaceae—35 (4%), Apiaceae—30 (3.6%). The dominant genera are *Astragalus*—33, *Erygeron*—19, *Veronica*—16, *Allium*—16, *Ranunculus*—15, *Artemisia*—12 species.

High-mountain plants growing in the subalpine and alpine zones make up 30% of the flora including 254 species from 129 genera and belonging to 38 families. The dominant families are Asteraceae—39 species (15.4%), Ranunculaceae—27 (10.6%), Poaceae—16 (6.3%), Scrophulariaceae—14 (5.5%), Apiaceae—13 (5%), Caryophyllaceae—11 (4.3%), Fabaceae—10 (4%), Lamiaceae—10 (4%), Rosaceae—10 (4%), Brassicaceae—9 (3.5%), Caprifoliaceae—9 (3.5%), The dominant genera are *Ranunculus*—8, *Saxifraga*—7, *Rhodiola*—5, *Draba*—5, *Polygonum*—5. Among them, 25 species grow in the alpine belt, on the old moraine soils, on sandy and stony slopes, on talus and stone soil bottoms up to the elevation of 4000 m, close to glaciers and snow fields. These are *Erigeron heterochaeta* (Benth. ex Clarke) Botsch., *E. pallidus* M. Pop., *E. olgae* Regel et Schmalh., *Dracacephalum origanoides* Steph., *D. grandiflorum* L., *D. stamineum* Kar. et Kir., *Festuca coelestis* (St-Yves) V.I. Krecz. et Bobrov.

There are 15 (1.8%) endemics distributed here: *Atragene sibirica* L., *Limonium dichroanthum* (Rupr.) Ik.-Gal., *Primula minkwitziae* W.W. Sm., *Rosularia turkestanica* (Regel et C. Winkl.) A. Berger, *Cotoneaster oliganthus* Pojark., *Oxytropis macrocarpa* Kar. et Kir., *Aulacospermum tianschanicum* (Korov.) C. Norm., *Scutellaria subcaespitosa* Pavl., *Pseuderemostachys sewerzowii* (Herd.) M. Pop., *Echinops talassicus Golosk.*, *E. fastigiatus* R. Kam.et Tscherneva, *Cousinia kazachorum* Juz. et Tschern., *C. triflora* Schrenk, *Allium trachyscordum* Vved., *A. talassicum Regel.*

In addition, there are 30 rare plant species listed in the Red List of Kazakhstan (2006). Trees and shrubs are represented by seven species—*Malus sieversii* (Ledeb.) M. Roem., *Juniperus seravschanica* Kom., *Celtis caucasica* Willd., *Sorbus persica* Hedl., *Ribes janczewskii* Pojark., *Louiseania ulmifolia* (Franch.) Pachom., *Abelia corymbosa* Regel et Schmalh, *Armeniaca vulgaris* Lam. The rest of the species

Table 1.7 Ecological-physiognomic types of vegetation in the southern Altai Mountains

Vegetation type	Vegetation subtype	Main community types
Arboreal	Light coniferous forest	Communities dominated by: *Larix sibirica*, with *Vaccinium myrtillus*, *Hylocomium proliferi*, *Pleurosium schreberi*, *Spiraea chamaedrifolia*, *Lonicera altaica*, *Ribes atropurpureum*, *Aconitum leucostomum*, *Paeonia anomala*, *Dactylis glomerata*, *Chamaenerium angustifolium*. *Trollius altaicus*, *Bupleurum longifolium*, *Geranium pseudosibiricum*, *Seseli condensatum*, *Luzula sibirica*, *Hieracium korshinskyi*, *Thalictrum simplex*
	Dark coniferous forest	Communities dominated by: *Picea abovata*, *Abies sibirica*, *Pinus sibirica*, with *Lonicera altaica*, *Vaccinium myrtillus, Spiraea media*, *S. chamaedrifolia*, *Cotoneaster melanocarpa*, *Ribes atropurpureum*, *Carex macroura*, *Deschampsia cespitosa*, *Calamagrostis langsdorffii*, *Helictotrichon hookeri*, *Geranium pseudosibiricum*, *Chamaenerium angustifolium*, *Luzula sibirica*, *Linnaea borealis*, *Hylocomium proliferi*, *Pleurosium schreberi*, *Aconitum leucostomum*, *A. decipiens*
	Deciduous forest	Communities dominated by: *Populus laurifolia*, *P. canescens*, *P. tremula*, *Betula pendula*, with *Salix pyrolifolia*, *S. viminalis*, *S. rorida*, *Rosa laxa*, *Crataegus chlorocarpa*, *Viburnum opulus*, *Lonicera tatarica*, *Spiraea media*, *Dactylis glomerata*, *Bromopsis inermis*, *Calamagrostis epigeios*, *Agrostis gigantea*, *Helictotrichon pubescens*, *Filipendula ulmaria*, *Inula helenium*, *Sanguisorba officinalis*, *Mentha arvensis*, *Angelica decurrens*, *Lupinaster pentaphyllus*, *Lathyrus pratensis*, *Allium flavidum*
	Floodplain forest	Communities dominated by: *Betula pendula*, *Salix pentandra, S. rosmarinifolia*, *S. jenisseensis*, *Padus avium* with *Picea obovata*, *Myricaria bracteata*, *M. squarrosa*, *Pentaphylloides fruticosa, Ribes nigrum*, *Carex aterrima*, *Deschampsia cespitosa*, *Lupinaster pentaphyllus*, *Chamaenerium angustifolium*, *Aconitum leucostomum, Caltha palustris, Linnaea borealis, Pyrola rotundifolia*, *Equisetum palustre*, *Filipendula ulmaria*, *Geum rivale*
Shrubby	Xeromesophytic dwarf semishrub	Communities dominated by: *Spiraea hypericifolia*, *S. chamaedrifolia*, *Amygdalus ledebouriana, Rosa pimpinellifolia*, *Lonicera tatarica*, *L. altaica*, *Ribes atropurpureum*, *Rubus idaeus*, *Daphne altaica*
	Petrophytic dwarf shrub	Communities dominated by: *Juniperus sibirica*, *Cotoneaster pojarkovae*, *Spiraea trilobata*, *Caragana frutex*, *Lonicera microphylla*
Steppe	Desert steppe	Communities dominated by: *Stipa sareptana*, *Festuca valesiaca*, *Koeleria cristata*, *Artemisia sublessingiana*, *A. gracilescens, A. compacta*
	Dry steppe	Communities dominated by: *Stipa capillata, S. lessingiana, S. zalesskii*, *Festuca valesiaca*, with *Koeleria cristata*, *Phleum phleoides*, *Cleistogenes squarrosa*, *Agropyron tarbagataicum*, *Jurinea multiflora, Galium ruthenicum*, *Iris scariosa*, *Dianthus rigidus, Galatella tatarica*, *Artemisia frigida*, *A. marschalliana*

Table 1.7 (continued)

Vegetation type	Vegetation subtype	Main community types
	Meadow steppe	Communities dominated by: *Stipa lessingiana*, *S. kryloviana*, *Festuca valesiaca*, *Helictotrichon altaicum*, with *Achillea nobilis*, *Galium verum*, *Pulsatilla multifida*, *Ziziphora clinopodioides*, *Fragaria viridis*, *Lathyrus gmelinii* and shrubs (*Rosa pimpinellifolia*, *Spiraea hypericifolia*)
	Xeropetrophytic shrubby steppe	Communities dominated by: *Stipa lessingiana*, *S. sareptana*, *S. capillata*, *Festuca valesiaca*, *Koeleria cristata, Helictotrichon altaicum*, *Carex pediformis*, with shrubs (*Spiraea trilobata*, *S. hypericifolia*, *Juniperus pseudosabina*) and herbs (*Centaurea sibirica*, *Patrinia intermedia, Orostachys spinosa*, *Phlomoides alpina*, *Allium rubens*, *Centaurea sibirica*, *Thalictrum foetidum*)
Meadow	Mountain rich forb-grass meadows	Communities dominated by: *Calamagrostis langsdorffii*, *Dactylis glomerata*, *Alopecurus pratensis*, *Brachypodium pinnatum*, *Helictotrichon pubescens*, *Agrostis gigantea*, *Cirsium helenioides*, *Delphinium elatum*, *Aconitum leucostomum*, *Veratrum lobelianum*, *Heracleum dissectum*. *Geranium albiflorum*, *Viola disjuncta*, *Vicia cracca*, *Lathyrus pratensis*, *Phlomoides tuberosa*, *Stemmacantha carthamoides*
	Floodplain-valley swamp meadows	Communities dominated by: *Deschampsia cespitosa*, *Alopecurus pratensis*, *Dactylis glomerata*, *Calamagrostis langsdorffii*, *Phragmites australis*, *Carex cespitosa*, *C. vesicaria*, *Parnassia palustris*, *Geranium albiflorum*, *Hylotelephium triphyllum*, *Stellaria palustris*, *Angelica decurrens*, *Filipendula ulmaria*, *Ligularia altaica*, *Scirpus sylvaticus*, *Sanguisorba officinalis*, *Thalictrum simplex*, *Ranunculus repens*
	Floodplain- valley true meadows	Communities dominated by: *Bromopsis inermis*, *Leymus ramosus*, *Elytrigia repens*, *Dactylis glomerata*, *Alopecurus pratensis*, *Calamagrostis epigeios*, *Helictorichon pubescens*, *Aconitum decipiens*, *A.anthoroideum*, *Bupleurum multinerve*, *Gentianopsis barbata*, *Geranium collinum*
	Floodplain- valley steppe meadows	Communities dominated by: *Stipa kirghisorum*, *S. sareptana*, *Festuca valesiaca*, *F. pseudoovina, Koeleria cristata*, *Poa transbaicalica*, *Bromopsis inermis*, *Galium verum*, *Achillea nobilis*, *Artemisia armeniaca*, *Dianthus superbus*, *Tanacethum achilleifolium, Alcea nudiflora*, *Centaurea ruthenica*, *Hypericum perforatum*, *Medicago falcata*, *Phlomis tuberosa*, *Paeonia hybrida*
	High-mountain subalpine meadows	Communities dominated by: *Helictotrichon pubescens*, *Elymus* sp., *Anthoxanthum odoratum*, *Phleum phleoides*, *Bistorta elliptica*, *Crepis chrysantha*, *Alchemilla ledebourii*, *Antennaria dioica*, *Phlomoides alpina*
	High-mountain alpine meadows	Communities dominated by: *Dactylis glomerata*, *Phleum alpinum*, *Deschampsia koeleroides*, *Carex stenocarpa*, *C. aterrima*, *Antennaria dioica*, *Omalotheca norvegica*, *Allium ledebourianum*

Table 1.7 (continued)

Vegetation type	Vegetation subtype	Main community types
Swamp	Tussock hollow sedge swamps	Communities dominated by: *Carex cespitosa*, *C. acuta*, *Calamagrostis langsdorffii*, *Juncus filiformis, Deschampsia cespitosa*, *Sanguisorba officinalis*
	Forb-sedge swamps	Communities dominated by: *Carex cespitosa*, *C. acuta*, with *Dactylis glomerata*, *Calamagrostis langsdorffii*, *Deschampsia cespitosa*, *Filipendula ulmaria*, *Veronica spicata*, *Mentha aquatica*
	Reed swamps	Communities dominated by: *Scirpus sylvaticus* with *Carex, Juncus filiformis, Agrostis gigantea*, *Poa palustris*, *Vicia cracca, Stellaria palustris*, *Veronica longifolia, Lathyrus pratensis, Trollius altaicus*, *Filipendula ulmaria*
	High-mountain sedge–cotton-grass swamps	Communities dominatied by: *Eriophorum angustifolium*, *Carex caryophyllea*, with *Salix* sp., *Betula rotundifolia*, *Allium ledebourianum, A. schoenoprasum, Pedicularis compacta*, *Swertia obtusa*
	Moss swamps	Communities dominated by: *Mnium*, *Bryum*, *Sphagnum* with *Carex* sp., *Eriophorum angustifolium*, *Allium schoenoprasum*
Tundra	Sedge–grass tundra	Communities dominated by: *Festuca kryloviana*, *Carex melanocarpa*, with *Trisetum spicatum*, *Anthoxantum odoratum, Luzula sibirica*, *Poa alpina*, *Potentilla evestita, Tripleurospermum ambiguum*, *Dracocephalum grandiflorum*, *Salix turczaninowii*
	Meadow-kobresia tundra	Communities dominated by: *Kobresia myosoroides*, with *Festuca kryloviana*, *Rhodiola quadrifida*, *Salix glauca*, *S. turczaninowii*, *S. vestita*
	Dryad tundras	Communities dominated by: *Dryas oxyodonta* with *Festuca ovina*, *Rumex alpestris*, *Ranunculus altaicus*, *Lagotis integrifolia*, *Rhodiola quadrifida*, *Potentilla gelida, Eritrichium villosum, Papaver nudicaule*, *Huperzia selago*, *Patrinia sibirica, Leiospora exscapa*
	Lichen tundra	Communities dominated by: Cladonia, Cetraria, with *Festuca kryloviana*, *Trisetum spicatum*, *Gentiana algida*, *Schulzia crinita*, *Swertia obtusa*, *Salix glauca*, *S. turczaninowii*, *S. vestita*
	Dwarf shrub tundra	Communities dominated by: *Betula rotundifolia* with *Salix glauca*, *S. reticulata*, *S. lanata*, *Lonicera hispida*, *L. altaica*, *Ribes fragrans*
	Gravel and stony tundra	Single plants and micro-groups of *Cortusa altaica, Saxifraga sibirica*, *Macropodium nivale, Oxyria digyna, Rhodiola algida*, *Paraquilegia anemonoides*, *Bergenia crassifolia*, *Festuca kryloviana*, *Trisetum spicatum*, *Anthoxanthum odoratum*

are perennial herbs which mostly grow in low-and medium mountain steppes. Two species reach the subalpine belt: *Juno orchioides* (Carr.) Vved., *Pseuderemostachys sewerzowii*. *Aconitum talassicum* Popov, *Allochrusa gypsophiloides* (Regel) Schischk*., Armeniaca vulgaris, Kosopoljanskia turkestanica* Korovin., *Abelia corymbosa, Iridodictyum kolpakowskianum* (Regel) Rodionenko*, Rheum wittrockii* Lundstr. belong to the Central Asian endemic plants. Narrow endemics growing on several mountain ridges (the Talass, Kyrghyz, Syr Darya Karatau Mountains) are represented by *Astragalus trichanthus* Golosk., *Scutellaria subcaespitosa*, *Pseudoeremostachys sewerzowii*, *Chondrilla kusnezovii* Iljin, *Stemmacantha aulieatensis (Iljin) Dittrich. Echinops fastigiatus* R. Kam.et Tscherneva*, Cousinia rigida* Kult., *C. vavilovii* Kult., *Tulipa zenaidae* Vved. Are found only in the Kyrghyz Alatau. On the frontier range: there are *Celtis caucasica, Sorbus persica, Louiseania ulmifolia, Pistacia vera* L. The main reasons to list the species in the Red Book include the reduced number of plants and intensive economic activities (plowing, grazing, collection of beautiful and medicinal plants, felling). Local endemics and species on the range frontier are the most vulnerable plants under threat.

Over 75 species of crop wild relatives are found here, including forage plant species such as *Elytrigia repens, Bromopsis inermis, Lathyrus pratensis, Vicia cracca, Phragmites australis, Dactylis glomerata, Trifolium repens, T. pretense*. The medicinal plants are: *Mentha longifolia, Hypericum perforatum, Ziziphora clinopodioides, Ephedra equisetina, Origanum vulgare, Achillea asiatica, A. millefolium, Glycyrrhiza glabra, G. uralensis*; food crops: *Allium caeruleum, A. caesium, Artemisia dracunculus;* fruit and nut crops found here are: *Malus sieversii, Pirus regelii, Armeniaca vulgaris, Cerasus tianschanica, Rubus caesus, Hyppophae rhamnoides, Rosa platyacantha, Crataegus songorica, Pistacia vera;* cereal crops are: *Taeniatherum crinitum, Aegilops cylindrica, Bromus macrostachys, B. japonicus, Hordeum leporinum*.

A special “Kyrghyz type of altitudinal zonality” has been identified (Rachkovskaya et al. 2003), which reveals transitional features of the north and west Tien Shan vegetation, showing the fragmented nature of the forest belt, abundance of ephemerals and ephemeroids in the steppe belt on foothill plains and mountain trails (Rachkovskaya et al. 2003; Aralbay et al. 2007). Juniper open woodland belt is common for the west Tien Shan region.

1.5.17 The Foothill Desert Belt (400–500 m a.s.l.)

The foothill desert belt (400–500 m a.s.l.) is distinguished by ephemeroid sagebrush vegetation with grasses: feather grass–sagebrush with ephemeroids (*Artemisia semiarida, Stipa sareptana, S. richteriana, Poa bulbosa*), and *Artemisia semiarida—Kochia prostrata—Ceratocarpus utriculosus* communities. The community composition is often participated by sedges (*Carex pachystylis, C. stenophylloides*). Sagebrush dwarf semishrubs predominate. The community composition is participated by bunch grasses, which predetermine the steppe features of foothill deserts. A similar role is also played by ephemeroid low grass savannoids (*Taeniatherum* *crinitum*, *Poa bulbosa*, *Hordeum brevisubulatum, H. leporinum, Aegilops cylindrica*). Frequently they become subdominants in plant communities under average human impact. Foothill plants are subjected to severe human-induced changes, basically connected with agricultural production (arable lands, rangelands). Along irrigation ditches, small reed (*Leymus multicaulis, L. angustus*), reed (*Phragmites australis*), and licorice (*Glycyrrhiza uralensis*) thickets are widespread.

1.5.18 The Steppe Belt

The steppe belt is divided into three sub-belts.

1.5.18.1 The Desert Steppe Sub-belt (500–800 m a.s.l.)

The desert steppe sub-belt (500–800 m a.s.l.) is represented by the communities of ephemeroides with dwarf subshrubs and bunch grasses: ephemeroid–sagebrush–feather grass (*Stipa sareptana, S. lessingiana, S. caucasica, Festuca valesiaca, Artemisia* spp.*, Kochia prostrata, Poa bulbosa*) with shrubs (*Spiraea hypericifolia, Cerasus tianschanica,* species of *Atraphaxis, Rosa*), sometimes in combination with petrophytic shrub communities (*Artemisia rutifolia, A. juncea, Ephedra intermedia, Convolvulus tragacanthoides*) is the common sight here. In the springtime, ephemeral synusium (*Bromus japonicus, Anisantha tectorum*) is abundant with ephemeroids (*Poa bulbosa,* species of *Gagea, Tulipa*). Gallery floodplain forests are formed by willow (*Salix alba*) and hawthorn (*Crataegus songoricus*). The shrub layer is represented by *Rubus caesus*, *Rosa beggeriana*, *Halimodendron halodendron,* the grass layer—by *Phragmites australis, Pseudosophora alopecuroides*. On high river terraces and in other automorphic habitats, *Artemisia sublessingiana* is often predominating.

1.5.18.2 The Savannoid Steppe Belt (800–1200 m a.s.l.)

The savannoid steppe belt (800–1200 m a.s.l.) is represented by ephemeroid–forb–bunch grass and ephemeroid–bunch grass vegetation together with ephemeroid–forb–feather grass–fescue (*Festuca valesiaca, Stipa capillata, Elytrigia trichophora, E. repens, Botriochloa ischaemum, Hypericum scabrum, Eremurus tianschanicus*) communities and shrubs (*Spiraea hypericifolia, Atraphaxis pyrifolia*) as well as thorn cushion plants (*Allochrusa paniculata*). Steppes are mixed with shrub thickets, rocks and screes. The phytocoenotic diversity within the sub-belt is connected with gallery forests extending along the mountainous flows. The wood layer is composed basically from *Acer semenovii,* hawthorn species (*Crataegus korolkovii, C. sanguinea, C. turkestanica, C. songorica*), willow (*Salix alba*). Shrubs are represented by dog rose (*Rosa beggeriana, R. platyacantha*), blackberry (*Rubus caesus*), sea buckthorn (*Hyppophae rhamnoides*); in grass layer *Elytrigia* *repens, E. trichophora*, *Mentha longifolia*, *Cynodon dactylon* are widespread. On dry stony slopes, cherry trees (*Cerasus erythrocarpa*, *C. tianschanica*) are met with low abundance. Apple thickets (*Malus sieversii*) and pear trees (*Pyrus regelii*) are quite rare. Savannoids are abundant in grass layer (*Bromus macrostachys, Aegilops cylindrica, Botriochloa ischaemum, Taeniatherum crinitum, Hordeum leporinum*); often they form microcoenoses.

The richest phytocoenotic diversity is formed in the inter-mountainous gorges and river valleys. Each valley has its typical and unique view. The Shunkyr River valley forms several side branches. Floodplain forests are formed by white willow (*Salix alba*), in shrub layer, apart from hawthorn and blackberry, *Lonicera tatarica, Cotoneaster multiflora* are found. The species composition of meadows is abundant with valuable fodder crops (*Elytrigia repens, Calamagrostis pseudophragmites*), liquorice (*Glycyrrhiza uralensis*), and estragon wormwood (*Artemisia dracunculus*). *Equisetum ramosissimum, Plantago lanceolata, Inula britannica, Galium aparine, Medicago falcata*, etc., are also distributed here. On high river terraces, sagebrush communities are spread (*Artemisia sublessingiana*) with participation of weeds (*Centaurea squarrosa, C. cyanus, Acroptilon australe, Peganum harmala*). On slopes, shrub thickets of dog rose, spirea, and honeysuckle are along with Tien Shan cherry; in grass layer, couch grass and ephemeral savannoids are found. A bright aspect is made by *Eremurus tianschanicus*, *Delphinium biternatum*, *Salvia deserta*.

In the Soghety River valley, *Acer semenovii, Crataegus songorica* predominate in the floodplain forests. Dog rose species are found in shrub layer, grass layer is formed by meadow grasses: *Elytrigia repens*, *Festuca pratensis*, *Bromopsis inermis*. On the western steep slopes, forbs grass–dwarf shrub communities are spread. Shrub layer is formed by *Cerasus tianschanica, Rosa platyacantha, Atraphaxis pyrifolia, A. virgata, Spiraea hypericifolia*. Herbs are represented by *Elytrigia repens, Poa bulbosa, Origanum vulgare*. The plant cover is used for grazing; in some places it has degraded with *Hulthemia persica* and *Centaurea squarrosa* showing degradation indices.

The Almaly (apple) gorge forest layer is mainly composed by *Acer semenovii, Malus sieversii*. Shrub layer is formed by *Rosa beggeriana, Rubus caesus*. Floodplain meadow vegetation consists of grasses and forbs with predomination and high abundance of legumes (*Lathyrus pratensis, Vicia cracca*). Eastern slopes are occupied by fescue steppe with herbs (*Elytrigia repens, Glycyrrhiza glabra, Galium verum, Hypericum scabrum*). The plants are used for grazing, the impact is often severe, which is shown by the abundance of weeds and unpalatable species: *Centaurea squarrosa, Artemisia serotina, Dodartia orientalis, Hulthemia persica*.

The gallery forests in the Koghershin gorge are formed by the following plants: *Crataegus songorica, C. korolkowii, Salix alba, Acer semenovii*. Shrub layer is represented by *Rubus caesus, Spiraea hypericifolia, Rosa beggeriana, Cotoneaster melanocarpa, Atraphaxis pyrifolia*. The species composition of flood meadows is as follows: *Elytrigia repens, E. trichophora, Medicago falcata, Hypericum perforatum, Achillea asiatica, Sanguisorba officinalis, Mentha longifolia, Allium caeruleum*. Groups of species *Impatiens parviflora* occur in some places (up to 10 %), indicating the habitat disturbance.

The Kaiyndy (birch) gorge forests are formed by *Betula tianschanica, Malus sieversii, Salix alba. Acer negundo, Ulmus pumila,* and are frequent in the forest layer, coming from cultivated plantations. Shrub layer has hawthorn, blackberry, apricot undergrowth. Floodplain meadows have high grasses (up to 200 cm), predominated by *Elytrigia repens*, *Achillea millefolium, Festuca pratensis, Allium caeruleum, Bromopsis inermis*. Other components of the communities are: *Scaligeria setacea, Daucus carota, Phleum paniculatum, Nepeta pannonica, Delphinium biternatum, Veronica spuria, Alcea nudiflora.*

In the western Kyrghyz Alatau range, the sub-belt comprises northern-most pistachio habitat. Woodlands with pistachio (*Pistacia vera*), Semyonov maple trees, Regel pear are found on dry stony steep slopes of the south-western exposure.

1.5.18.3 The Meadow Steppe Sub-Belt (1200–1600 m a.s.l.)

The meadow steppe sub-belt (1200–1600 m a.s.l.) is represented by rich forb-grass–fescue communities like: *Festuca valesiaca*, *Phleum phleoides, Dactylis glomerata*; meadow-steppe forbs: *Salvia deserta, Nepeta pannonica, Galium verum,* with *Stipa capillata, S. kirghisorum, Helictotrichon schellianum, Phlomoides pratensis, Geranium collinum,* in combination with shrub thickets *Spiraea hypericifolia, Rosa spinosissima, Atraphaxis pyrifolia*, sometimes with juniper woodlands like *Juniperus semiglobosa, J. pseudosabina*. *Eremurus regelii, E. tianshanicus, E. cristatus*, constitute the herbal layer. Cereals (*Taeniatherum crinitum, Aegilops cylindrica, Botriochloa ischaemum*) occur in stony habitats. The vegetation of the Karabulak inter-mountainous valley is unique and diverse in species. At an elevation of 1485 m a.s.l., rich forb-grass meadow steppes are distributed. The herbage is basically composed of *Elytrigia trichophora, E. repens, Festuca valesiaca, including Salvia deserta, Scaligeria setacea, Nepeta pannonica, Achillea millefolium, A. asiatica, Potentilla asiatica, Potentilla impolita, Pseudohandelia multifida, Senecio jacobea, Senecio erucifolius, Dipsacus dipsacoides, Origanum vulgare, Hypericum perforatum*. Species such as *Medicago falcata, Lathyrus tuberosus* are less abundant. At an elevation of 1558 m a.s.l., grass-rich forb (*Eremostachys fetisowii, Trifolium hybridum, Lathyrus pratensis, Allium caesium, A. caeruleum, Betonica foliosa, Nepeta pannonica, Rumex confertus, Potentilla asiatica*) communities are typical. Grass cover is formed by *Dactylis glomerata, Elytrigia repens, Bromopsis inermis, Festuca valesiaca*. The plants of the valleys are used for haymaking.

Willow and Semyonow maple trees form floodplain forests. *Rosa beggeriana, Lonicera microphylla, Euonimus semenovii, Rubus caesus, Berberis sphaerocarpa* are presented in the shrub layer. High grasses of *Melica altissima, M. transsilvanica, Phalaroides arundinacea* occur in herbal layer. Forb meadows are formed by *Amoria repens, Trifolium hybridum, Plantago major, P. longifolia, Festuca arundinacea,* close to the water there is *Veronica anagalis-aquatica, Mentha longifolia*. Meadow vegetation on high river terraces is forb grass with predominating *Elytrigia repens* and abundant milfoil (*Achillea millefolium*). Species such as *Potentilla impolita, P. asiatica, Galium verum, Ligularia thomsonii, Ligularia heterophylla,* *Dipsacus dipsacoides, Allium caeruleum, Conium maculatum, Lathyrus pratensis* are found among forbs. On stony cliffs, single plants of *Armeniaca vulgaris, Crataegus songorica, Juniperus semiglobosa, Ephedra intermedia* occur. Savannoid groups tend to grow on dry slopes.

In the Merke and Kaiyndy gorges, the recreation impact is severe. The abundance of *Impatiens parviflora, Urtica dioica* has increased in the grass layer. Frequently, coverage of species *Impatiens parviflora* reaches 50–60 %.

1.5.18.4 The Juniper Woodland Belt (1600–2200 m a.s.l.)

The juniper woodland belt (1600–2200 m a.s.l.) is represented by juniper–shrubby woodlands (*Juniperus pseudosabina, J. semiglobosa, Rosa platyacantha, Spiraea lasiocarpa, Atragene sibirica*) in combination with steppes (*Festuca valesiaca, Helictotrichon schellianum, Stipa kirghisorum, Phleum phleoides, Phlomoides pratensis*) and meadows. In the Kogeshin gorge, juniper woodlands are usually combined with grass-forb meadows, forb-grass meadow steppes, and shrub thickets. Juniper woodlands (*Juniperus semiglobosa*) tend to grow on steep slopes. In the lower part of slopes, there are dense shrub thickets dominated by *Rosa spinosissima*, *R. beggeriana, Cotoneaster uniflora, Lonicera microphylla*. Grass layer has meadow species: *Campanula glomerata, Veronica spuria, Lathyrus pratensis, Origanum vulgare, Achillea asiatica, Thalictrum collinum*. On gentle slopes and valleys, tall-grass-herb meadow steppes are distributed. The plant cover is disturbed due to grazing. There are sites with severe degradation—in cattle stands. At primary stages, the manured sites of rangelands overgrow with *Malva pusilla, Rumex confertus*.

Dense shrub thickets are formed along river flows with *Rosa platyacantha, R. beggeriana, Spiraea hypericifolia, Spiraea lasiocarpa, Sorbus tianshanica, Lonicera microphylla, Salix triandra*. Grass layer is dense, formed by *Melica transsilvanica, M.altissima, Bromopsis inermis, Festuca pratensis, Phleum phleoides, Patrinia intermedia, Delphinium oreophyllum, Allium caesium, Medicago falcata, Potentilla impolita,* etc. On stony slopes, *Ephedra equisetina, Atraphaxis pyrifolia* grow.

In the eastern part of the Kyrghyz Alatau range (Kyrghystan), at an elevation of 2000 m, spruce stands of *Picea schrenkiana* are found on the bottoms and abrupt slopes of gorges. There is shrub layer of *Juniperus pseudosabina, Berberis sphaerocarpa, Lonicera hispida* and herbaceous cover of *Dactylis glomerata, Poa nemoralis, Ligularia heterophylla* in these stands (Rachkovskaya et al. 2003).

1.5.19 The Belt of Subalpine Meadows and Prostrate Juniper Thickets (2200–2800 m a.s.l.)

The belt of subalpine meadows and prostrate juniper thickets (2200 to 2800 m a.s.l.) have typically grass-rich-forb, forb-grass meadows (*Phlomoides oreophila,* *Bistorta elliptica*, *Poa pratensis, Poa angustifolia, Phleum phleoides, Dactylis glomerata*) with prostrate taxa (*Juniperus pseudosabina*) and tree juniper (*Juniperus semiglobosa*), as well as steppe communities on dry slopes (*Festuca valesiaca, Helictotrichon schellianum, Ziziphora clinopodioides, Potentilla nivea, P. bifurca*). Forb-grass meadows run along river beds and ravines. Herbal cover is formed by *Phleum phleoides, Poa angustifolia, Alopecurus pratensis*. *Phlomoides oreophila, Trifolium pratense, Amoria repens, Rhodiola kirilovii, Miosotis asiatica, Iris ruthenica, Alchemilla retropilosa, Alchemilla sibirica, Aconogonon alpinum, Lamium album, Achillea millefolium, Artemisia santolinifolia*. Plants are used for grazing, degradation is severe. In this belt, thorn cushion-like plants are met (*Acantholimon fetisowii, A. purpureum, A. alberti*).

1.5.20 The Alpine Belt of Cryophytic Meadows and Communities of Kobresia (2800–3500 m a.s.l.)

The alpine belt of cryophytic meadows and communities of Kobresia (2800–3500 m a.s.l.) is represented by xerophytic low-herb meadows with domination of *Alchemilla reptopilosa, Bistorta vivipara, Potentilla gelida, Festuca kryloviana, Poa alpina,* as well as *Kobresia humilis, K. capilliformis* communities. Kobresia communities are typical of the alpine belt only (3000–4000 m a.s.l.); they grow on plateau-like ridges, old moraine sediments, where soil erosion is almost absent (Rubtsov 1966). The tops of ridges are occupied by open aggregations of cryopetrophytes like: *Thylacospermum caespitosum, Rhodiola coccinea, Saxifraga flagellaris* (Rachkovskaya et al. 2003). On stony slopes: rocks, moraines, taluses, *Lonicera semenovii* and *Ephedra regeliana* grow; the cliff crevices, humid fine-grained slopes are covered by *Potentilla gelida, Waldheimia tomentosa, Saussurea gnaphalodes.*

According to ecological-physiognomic classification, in the Kyrghyz Alatau range there are six vegetation types: arboreal, shrubby, dwarf semishrub, meadow, steppe, savannoid (Table 1.8.).

Vegetation types are not always attached to altitudal zones. Arboreal plants can be found in all the belts, including subalpine meadows. Shrubby thickets reach the subalpine belt. Dwarf semishrub plants are typical of the steppe desert belt. Steppe vegetation covers a wide range of altitudes, from low up to high mountains. Meadow vegetation, occupying different areas, can be found from foothills up to high mountains. Savannoid vegetation is mostly spread in low mountain and sometimes occurs in foothills and mid-mountains.

Savannoid vegetation is an indigenous type, characteristic of south Kazakhstan and Central Asian foothills and low-mountain landscapes (Rubtsov 1955; Korovin 1961/1962; Karmysheva 1982; Rachkovskaya et al. 2003). Its origin is connected with loess sediments and with the formation of a special (ephemeral) vegetation development rhythm, when plants start in winter and spring seasons (Korovin 1961/1962), thus avoiding summer drought. The most typical species are: *Elytrigia trichophora, Botriochloa ischaemum, Eremurus tianschanicus, Alcea nudiflora,* there are subdominants and components of savannoid and meadow steppes.

Table 1.8 Ecological-physiognomic types of vegetation in the Kyrghyz Alatau range

Vegetation type	Vegetation subtype	Main community types
Arboreal	Evergreen juniper	Shrub–juniper (*Juniperus semiglobosa*, *J. pseudosabina*, *Rosa platyacantha*, *Spiraea lasiocarpa*, *Atragene sibirica*) woodlands
	Floodplain forest	Hawthorn–maple (*Acer semenovii*, *Crataegus korolkovii*, *C. sanguinea*, *C. turkestanica*, *C. songorica*) forests
		Birch (*Betula tianschanica*) forests with apple trees (*Malus sieversii*), willows (*Salix alba*) and apricot trees (*Armeniaca vulgaris*)
Shrubby	Petrophytic shrub thickets on stony soils and on rocks outcomes	Communities and groups of *Spiraea hypericifolia*, *Cerasus tianschanica*, *Cotoneaster multiflora*, *Atraphaxis pyrifolia*, *A. virgata*, *Rosa spinosissima*
		Shrub-sagebrush (*Artemisia rutifolia*, *A. juncea*, *Ephedra intermedia*, *Convolvulus tragacanthoides*) comunities
	Thickets of mesophilic and mesoxerophilic shrubs in river valleys	Communities dominated by *Rosa beggeriana, R. platyacantha*, *Rubus caesius*, *Hyppophae rhamnoides,Cotoneaster melanocarpa*, *Lonicera microphylla*, with *Euonimus semenovii*, *Berberis sphaerocarpa*
Dwarf semishrub	Bunch grass–sagebrush steppe deserts with ephemeroids in foothills	*Artemisia semiarida–Stipa sareptana*, *S. richteriana* with *Poa bulbosa* communities
		Artemisia semiarida–Kochia prostrata–Ceratocarpus utriculosus communities
Steppe	High-mountain steppes	Forb–fescue (*Festuca valesiaca*, *Helictotrichon schellianum*, *Ziziphora clinopodioides*, *Potentilla nivea*, *P. bifurca*) communities
	Mid-mountain meadow steppes	Rich forb-grass–fescue (*Festuca valesiaca*, *Stipa capillata*, *S. kirghisorum*, *Helictotrichon schellianum*, *Phleum phleoides*, *Dactylis glomerta*, *Elytrigia trichophora*, *E. repens*, *Bromopsis inermis*, *Salvia deserta*, *Napeta pannonica*, *Geranium collinum*) communities
		Rich forb-grass and grass-rich forb communities in intermountain valleys Grasses: *Festuca valesiaca*, *Elytrigia trichophora*, *E. repens*, *Bromopsis inermis*, *Dactylis glomerata* Forbs: *Scaligeria setacea*, *Achillea millefolium*, *A. asiatica*, *Potentilla asiatica*, *Dipsacus dipsacoides*, *Allium caeruleum*, *A. caesium*, *Hypericum perforatum*, *Betonica foliosa, Medicago falcata*

Table 1.8 (continued)

Vegetation type	Vegetation subtype	Main community types
	Low-mountain savannoid steppes	Hemiephemeroid–forb–feather-grass–fescue (*Festuca valesiaca*, *Stipa capillata*, *Phleum phleoides*, *Elytrigia trichophora*, *Botriochloa ischaemum*, *Hypericum scabrum*, *Eremurus tianschanicus*, *Alcea nudiflora*) communities
		Forb–fescue (*Festuca valesiaca*, *Stipa capillata*, *Allochrusa paniculata*, *Elytrigia repens*, *Carex turkestanica*, *Poa bulbosa*, *Centaurea squarrosa*, *Taeniatherum crinitum*) communities
		Fescue–wheat-grass (*Elytrigia trichophora*, *Festuca valesiaca*) communities
	Foothill desert steppes	Ephemeroid–sagebrush–feather-grass (*Stipa sareptana*, *S. lessingiana*, *S. caucasica*, *Festuca valesiaca*, *Artemisia sublessingiana*, *A. valida*, *Kochia prostrata*, *Poa bulbosa*) communities
Savannoid	Low-mountain savannoids	Ephemeroid (*Botriochloa ischaemum*, *Poa bulbosa*) communities
		Hemiephemeroid (*Eremurus tianschanicus*, *Alcea nudiflora*, *Delphinium biternatum*, *Convolvulus pseudo-cantabrica*, *Lagochilus platycalyx*) communities
		Ephemeral (*Aegylops cylindrica*, *Thaeniatherum crinitum*, *Bromus macrostachys*, *B. japonicus*, *Hordeum bulbosum*, *H. leporinum*) communities
Meadow	High-mountain low-herb alpine meadows	Kobresia–grass-forb (*Alchemilla retropilosa*, *Polygonum songaricum*, *Leontopodium campestre*, *Festuca alatavica*, *Poa calliopsis*, *Kobresia humilis*, *K. capilliformis*)
	High-mountain mid herb subalpian meadows	Forb-grass (*Poa angustifolia*, *Alopecurus pratensis*, *Phleum phleoides*, *Helictotrichon schellianum*, *Miosotis asiatica*, *Phlomoides oreophila*, *Trifolium repens*, *Cerastium davuricum*, *Bistorta major*, *Aconogonon alpinum*, *Geranium collinum*)
	Floodplain meadows	Forb-grass Grasses: *Elytrigia repens*, *E. trichophora*, *Calamagrostis pseudophragmites*, *Festuca pratensis*, *Bromopsis inermis*, *Phleum paniculatum*, *Melica altissima*, *M. transsilvanica*, *Phalaroides arundinacea* Forbs: *Glycyrrhiza uralensis*, *G. glabra*, *Plantago lanceolata*, *Inula britannica*, *Galium aparine*, *Medicago falcata*, *Mentha longifolia*, *Cynodon dactylon*, *Achillea millefolium*, *Allium caeruleum*, *Daucus carota*, *Nepeta pannonica*, *Veronica spuria*, *Lathyrus pratensis*, etc.

The vegetation of the Kyrghyz Alatau range has undergone human-induced changes. In general, the degradation degree is medium. Sometimes, severely impacted sites are located. Steep slopes are disturbed slightly. Grazing, haymaking, and recreation are the basic impact factors.

1.5.21 The Western Tien Shan Mountains

The Western Tien Shan flora of vascular plants within the territory of Kazakhstan includes 1491 species (Karmysheva 1982) from 483 genera and 91 families, which makes up 28% of the whole vascular plant flora in Kazakhstan. Dominant families are Asteraceae—230 species (16.2%), Fabaceae—147 (10.4%), Poaceae—127 (9.0%), Lamiaceae—76 (5.4%), Apeaceae—75 (5.3%), Rosaceae—70 (4.9%), Cariophyllaceae—64 (4.5%), Brassicaceae—62 (4.4%), Ranunculaceae—54 (3.7%), Scrophulariaceae—49 (3.4%). Dominant genera are *Astragalus*—67, *Oxytropis*—27, *Cousinia*—25, *Allium*—24, *Carex*—22, *Veronica*—21, *Erigeron*—18, *Gagea*—17, *Potentilla*—17, *Poa*—15.

This part occupies a marginal location and borders on desert plains, which results in the impact of dry eastern and north-eastern winds. Low precipitation is observed in summer months and early autumn, which determines the xerophytic vegetation type, prevaillance of herbs in the floristic composition, in particular, xerophytic and mesoxerophilic species, as well as communites that they form: destitute timber plants.

On the basis of life-forms, the western Tien Shan flora can be distinguished as follows: trees—27 species, arborous shrubs—9 species, shrubs—67, dwarf shrubs—12, semishrubs—24, dwarf semishrubs—12, lianas—3; perennial herbs—1011 species, biennials—56, annuals—231.

For the Aksu-Jabagly Nature reserve located in the Talass Alatau, Ivashchenko (2001) has developed a list of vascular plants. She has revised the data of Karmysheva (1982, 1983) and completed the list with the results of her own studies. Her list numbers 1312 species, including 37 species recorded in the Red List of Kazakhstan (2006): *Dryopteris mindshelkensis* N. Pavl., *Adiantum capillus-veneris* L., *Juniperus seravschanica* Kom., *Stipa karataviensis* Roshev., *Arum korolkowii* Rgl., *Eminium lehmannii* (Bge) O. Ktze, *Colchicum luteum* Baker., *Tulipa greigii* Rgl., *Tulipa kaufmanniana* Rgl., *Allium pskemense* B. Fedtsch., *Ungernia sewerzowii* (Regel) B. Fedtsch., *Juno coerulea* (B. Fedtsch.) Poljakov, *J. orchioides* (Carr.) Vved., *Iridodictyum kolpakowskianum* (Regel.) Rodionenko, *Epipactis palustris* (L.) Crantz., *Betula talassica* P. Pol., *Celtis caucasica* Willd., *Rhaphidophyton regelii* (Bunge) Iljin, *Allochrusa gypsophiloides* (Regel.) Schischk, *Aconitum talassicum* M. Pop., *Pseudosedum karatavicum* Boriss., *Ribes janczewskii* Pojark, *Malus sieversii* (Ldb.) M. Roem., *M. niedzwetzkyana* Dieck., *Sorbus persica* Hedl., *Medicago tianschanica Vass., Oxytropis talassica* Gontsch., *Euonymus koopmannii* Lauche., *Kosopoljanskia turkestanica* Korovin., *Karatavia kultiassovii* (Korov.) Pimenov & Lavrova, *Primula minkwitziae* W.W. Sm., *Pseuderemostachys sewerzowii* (Herd.) M. Pop., *Morina kokanica* Rgl., *Lactuca mira Pavl., Cousinia* *grandifolia* Kult., *Centaurea turkestanica* Franch., *Ugamia angrenica* (Krasch.) Tz-vel., *Hippolytia megacephala* (Rupr.) Poljak.

The flora here is of highly endemic nature which may be related to the microendemism reported for some other mountainous areas (Uysal et al. 2011). There are about 557 Central Asian endemic species here (38 % of the total species number). Among these are the endemics pertaining to Kyrghyz Alatau—7 (1.9 %), Pamir-Alay–West Tien Shan—17 (2.5 %), and the Junggar Alatau—8 species; those pertaining to north Tien Shan are 69 species (12.3 %).

In the western Talass region, the following families are distinguished on the basis of number of endemic species: Asteraceae (six species), Apiaceae (four species), Fabaceae, Lamiaceae, Scrophulariaceae (three species in each). Each of the remaining families is represented by one species (Karmysheva 1982). From among the above endemics, there is only one tree species (*Betula talassica*), the rest are perennial grasses, lacking any dominants of the plant communities. Of subdominant importance are species of *Leymus flexilis* (Nevski) Tzvelev, *Schrenkia kultiassovii* Korovin., *Nepeta mariae* Regel., *Cousinia fetissowii* Winkl., *C. tianschanica* Kult., *Lactuca mira* Pavl. Zonal distribution of endemics is also irregular. Their richest diversity is found in mid-mountain (11 species) and subalpine belt (10 species); in low-mountain there are 6 species, in alpine belt—4, and 1 species in the nival belt: Some species occur in two adjacent belts.

Relict plants also occur: *Lepidolopha karatavica, L. komarowii*, *Thesium minkwitzianum,* which are considered by Pavlov and Lipshits (1934) to be living monuments of the ancient desert Mediterranean flora. *Pseuderemostachys sewerzowii* is classified as a representative of the Syr Darya Karatau and Western Tien Shan Tertiary flora. Pavlov (1970) identifies *Calophaca soongorica var. tianschanica* as a relict endemic. With this type of endemic, he also associates *Stephanocarium olgae* (B. Fedtsch.) M. Pop. and *Sergia sewerzowii* (Regel.) Fed. The last species occurs in the crevices of canyon rocks along the Mashat and Aksu rivers, while less often in the Sayramsu, Saryaygyr and Naut river canyons. Kamelin (1973) associates *Trichanthemis* and *Schrenkia* genera as Neogenic relict endemics.

There are 15 plant species threatened as a result of human activities: *Juniperus turkestanica* Kom, *Pistacia* vera L., *Malus sieversii, Betula talassica* Poljak., *Ephedra equisetina* Bunge, *Allium pskemense, A. longicuspis* Regel., *Korolkowia sewerzowii* Regel., *Rheum maximowiczii* Losinsk., *Allochrusa gipsophiloides, Oxytropis talassica* Gontsch., *O. auliatensis* Vved., *Hippophae rhamnoides* L. (Karmysheva 1982)

In protected areas (nature reserves and national parks), vegetation development and phytocoenoses formation are free from human-induced impact as reported for similar other areas (Ozturk 1998; Celik et al. 2003; Ozturk et al. 2012). A favorable effect of protected conditions is marked in the mountain vegetation. However, after many years of strict reserve regime, some of the low sites of grass meadows become filled with litter and weeds. Periodical haymaking is necessary to improve the meadow vegetation.

The western Tien Shan is rich in plant diversity with about 1500 plants, it also contains original ancestral forms of many economically important plants like: the species of *Rosa, Crataegus, Cerasus, Allium, Medicago tianschanica, Malus* *sieversii, Pyrus regelii, Hippophae rhamnoides, Amygdalus spinosissima, A. petunnikowii, Pistacia vera, Prunus sogdiana, Padellus mahaleb,* wild relatives of cereals (*Aegilops cylindrica, Hordeum bulbosum*), and ornamentals (*Tulipa, Juno, Eremurus*). A total of 103 species of wild relatives of economically important species have been identified in the region.

According to the existing classification of zonality types based on associating plant communities distribution with environmental factors (soil, relief, climate), the region relates to the Middle Asian group of altitudinal zonality types. Depending on humidity degree, two lines are distinguished in the Middle Asian group: wet line, typical of windward ridges of the western Tien Shan, and more droughty line in the Syr Darya Karatau (Rachkovskaya et al. 2003). The vegetation of the west Tien Shan ridges is characterized by a complete wet line zonality column of the Middle Asian group of altitudinal zonality types.

1.5.22 Belt of Low-Herb Savannoids (600–800 m a.s.l.)

Foothills are occupied with low-herb ephemeral–sedge–bluegrass communities (*Poa bulbosa, Carex pachystylis, Alyssum turkestanicum, A. dasicarpum, Anisantha tectorum, Taeniatherum crinitum*). Low-herb ephemeral and ephemeroid vegetation develops profusely in spring, grows only on low-mountain slopes, as the agricultural lands (arable lands, orchards, vineyards) reach close to hills.

1.5.23 Belt of High-Herb Savannoids and Xerophytic Deciduous Woodlands (800–1500 m a.s.l.)

In phytocoenotical aspect, this belt is heterogeneous and diverse. Its lower part is occupied by communities of tall herbs and cereals that exist for a long time in place of flattened woodlands. They are participated by *Elytrigia trichophora, Hordeum bulbosum, Eremurus regelii, Alcea nudiflora, Echinops spaerocephalum*; in upper slopes such communities are also composed of various shrub species, together with the endemic species for the western Tien Shan (*Calophaca tianschanica, Amygdalus petunnikowii*), and species with a wider Central Asian distribution (*Rosa kokanica, R. beggeriana, R. corymbifera, R. fedtschencoana*, *Crataegus pontica, C. turkestanica, Cotoneaster soongoricus*).

Along the mountain streams, tree and shrub vegetation includes the following species: *Juniperus semiglobosa, J. seravschanica, Malus sieversii, Betula tianschanica, Salix triandra, S. alba, Cotoneaster melanocarpus, Berberis integgerrima, Lonicera nummulariifolia, Hippophae rhamnoides*. In the Karzhantau western ridge gorges, *Prunus sogdiana, Crataegus turkestanica, Acer semenovii, Morus alba, Armeniaca vulgaris* also occur in the layer of trees; *Amygdalus spinosissima, Rubus caesius, Rosa corymbifera, R. kokanica, Spiraea hypericifolia* are found among the shrubs.

On the small sites, pistachio open woodlands as remanants of widely distributed stands can be found. More considerable areas are occupied by deciduous open woodlands of *Crataegus pontica, C. turkestanica, Malus sieversii,* sometimes with *Acer semenovii* and the cover of tall herbs and grasses. The stony and cobble slopes are overgrown with bunchgrass and forb–bunchgrass steppe communities dominated by *Festuca valesiaca, Elytrigia trichophora*, and participated by feather grass (*Stipa sareptana, S. hohenackeriana*). Walnut forests (*Juglans regia*) are sometimes found on the humid sites of slopes.

1.5.24 Belt of Juniper Woodlands (1500–2000 m a.s.l.)

Juniperus seravschanica and *J. semiglobosa* are widespread with *Acer turkestanicum*. Sometimes these species form quite dense stands (Pavlov 1970). In such juniper forests, mesophilic shrubs present are: *Lonicera microphylla, Cotonoaster soongoricus, Restella albertii*; herbaceous layer with hemiephemeroid tall herbs include *Prangos pabularia, Aconogonon coriarium, Ferula tenuisecta, F. prangifolia*. The herbaceous layer consists of mesophilic grasses and forbes (*Bromopsis inermis, Poa nemoralis, Achillea millefolium, Hypericum perforatum, Origanum tyttanthum, Dracocephalum nodilosum, Vicia cracca*), sometimes they are mixed with xerophilic grasses: *Festuca valesiaca, Elytrigia trichophora, Stipa sareptana, S. hohenackeriana.*

In the same belt, there are original walnut forests in humid "western corners" of the ridges. These forests do not form the belt in western Tien Shan and grow only in small groups on the slopes of northern exposure. Here, so-called complex walnut forests, in which (besides *Juglans regia*) *Malus sieversii,* and *Acer turkestanicum* participate, occur more often than others (Rachkovskaya et al. 2003). A rich layer of mesophyllous shrubs developes (*Exochorda tianschanica, Crataegus tianschanica, Lonicera nummulariifolia*) in these forests, herbaceous layer consists of forest mesophyllous species (*Brachypodium silvaticum, Poa nemoralis, Aegopodium tadshikorum*). On the driest internal slopes of the uppermost part of mid-mountain, juniper woodlands of *Juniperus turkestanica* and *J. semiglobosa* with steppe cover of *Festuca valesiaca, Poa angustifolia, Phleum phleoides* grow. Herbaceous layer is formed by *Abelia corymbifera, Lonicera altmannii*. As a whole, xerophytic types of juniper woodlands are not typical of the western Tien Shan Mountains.

1.5.25 Belt of Subalpine Meadows (2000–2800 m a.s.l.)

Tall umbellate communities— "umbellares" are the most usual ones for the lower part of the western Tien Shan high mountains (subalpine belt). The main dominants are *Prangos pabularia* and *Ferula tenuisecta.* Umbellares represent one of the prevailing vegetation types in the region. In addition to basic dominants, which are hemiephemeroids, some mesophyllous and xeromesophyllous species, as *Polygonum* *coriarium, Bromopsis inermis, Dactylis glomerata, Inula macrophylla,* sometimes *Festuca valesiaca* participate in the communities of umbellares.

In the same belt on northern slopes, where the Mediterranean rhythm of precipitation becomes weak, more mesophytic medium-herb meadows with genera like *Geranium, Polygonum, Phlomis* occur and take up larger areas than umbellares (Rachkovskaya et al. 2003). Prick herb coenoses with endemic *Cousinia bonvalotii* are confined mostly to slopes and saddles on a more or less developed fine-grained layer of soil. *Prangos pabularia, Ligularia alpigena, Onobrychis echidna* codominate the prick herb coenoses. Prostrate juniper communities of *Juniperus turkestanica* occupy the stony slopes of southern exposition.

1.5.26 Alpine Belt of Cryophytic Low-Herb Meadows (2800–3400 m a.s.l.)

The belt comprises communities of microthermal and xeromesophyllous herbaceous plants, cryophytic meadows with forbes (*Waldhemia tridactylites, Cerastium litospermifolium, Cystiocorydalis fedtschenkoana, Allium polyphillum*, etc.) and communities of *Carex stenocarpa, Kobresia cappiliformis, Puccinella subspicata, Festuca kryloviana, Helictotrichon hookeri, Hordeum turkestanicum, Poa alpina, Trisetum spicatum.* The species of *Ranunculus, Lagotis, Primula, Draba, Allium semenovii, A. kaufmannii* are predominant. On rock outcrops, screes, stony slopes of middle and highland belt cryopetrophytes occur: *Allium polyphillum, A. pskemense, Paraquilegia grandiflora, Delphinium oreophillum, Saxifraga albertii, Campanula capusii,* etc., in low and middle mountain belt, there are *Pentaphylloides parviflora, Artemisia rutifolia, Silene braghuica, Parrya albida, Eremurus lactifloris, Spiraea pilosa,* and others.

The wide presence of rocks and screes at all altitudes alters the traits of plant distribution. The role of slope exposure for some species is of greater importance than the altitude a.s.l. For instance, species typical of low mountain go up the sun-warmed sites and reach the subalpine altitudes (*Silene guntensis, Allium karataviense, Thalictrum isopyroides, Phlomoides brachystegia*), while high-mountain species go down the shady slopes to middle mountains and lower parts(*Draba arsenievii, Viola biflora, Aquilegia tianschanica, Saxifraga sibirica,* and others).

According to ecological-physiognomic classification, the vegetation of the western Tien Shan Mountains can be divided into six types: arboreal, shrubby, steppe, savannoid, meadow, and prick herbaceous plants (Table 1.9).

Arboreal vegetation type consists of juniper growth that lays the basis of mountainous forests in the western Tien Shan. Deciduous forests and woodlands are widespread in stream and rivulet valleys are also classified as arboreal vegetation type.

In general, the vegetation of the western Tien Shan ridges is medium disturbed, but sometimes severely degraded sites are found. Due to grazing, haymaking, and recreation impact, there is almost no natural vegetation in foothills. The degradation is also connected with cultivation and livestock production. Outside the protected

Table 1.9 Ecological-physiognomic types of vegetation in the western Tien Shan Mountains

Vegetation type	Vegetation subtype	The main community types
Arboreal	Evergreen juniper	Juniper (*Juniperus semiglobosa, J. seravschanica*) herbaceous woodlands:
		With meadow species (*Phleum phleoides, Poa angustifolia, Dactylis glomerata, Trifolium pretense*)
		With steppe species (*Stipa kirghisorum, Festuca valesiaca*)
		With savannoids (*Elytrigia trichophora, Hordeum bulbosum*)
		Maple–juniper woodlands with shrubs (*Acer turkestanicum, Lonicera microphylla, Cotoneaster soongoricus, Restella alberti*)
		Shrub–juniper woodlands with tall-herb savannoids (*Rosa* spp., *Pistacia vera, Cononoaster melanocarpa, Cerasus tianschanica, Elytrigia trichophora, Eremurus regelii, Alcea nudiflora*)
	Deciduous forests and woodlands	Forests with dominanting *Malus sieversii, Crataegus turkestanica, C. pontica;* with *Acer semenovii, Celtis caucasica*
		Floodplain forests of *Betula talassica, B. tianschanica, B. turkestanica, Salix niedzwieckii, S. picnostachya, S. alba*
		Hawthorn grooves (*Crataegus turkestanica*)
Shrubby	Thickets of deciduous shrubs	Thickets with prevailing *Rosa kokanica, R. fedtschenkoana, R. marocandica;* species of *Lonicera, Cotonoaster, Berberis;* with *Amygdalus spinosissima, Prunus sogdiana*
	Mesoxerophylous shrubs	Thickets with prevailing *Spiraea hypericifolia, Cerasus erythrocarpa, C. tianschanica, Atraphaxis pyrifolia*
	Evergreen prostrate juniper	Shrub–juniper (*Juniperus turkestanica, Lonicera humilis, Lonicera karelinii, Rosa albertii*) communities
Steppe	True steppes	Forb–bunchgrass (*Stipa kirghisorum, S. capillata, Festuca valesiaca, Helictotrichon desertorum, Ferula tenuisecta, Alcea nudiflora, Eremurus regelii, Elytrigia trichophora*) communities
	Steppes with savannoid elements	Forb–hemiephemeroid–fescue (*Festuca valesiaca, Poa bulbosa, Hordeum bulbosum, Ferula tenuisecta, Alcea nudiflora*) communities
		Forb–feather–grass communities:
		Stipa kirghisorum, Cousinia minkwitziae, Eremurus regelii
		Stipa capillata, Elytrigia trichophora, Hordeum bulbosum

Table 1.9 (continued)

Vegetation type	Vegetation subtype	The main community types
Meadow	High-mountain low-herb meadows	Communities with *Carex stenocarpa, Kobresia cappiliformis, Puccinellia subspicata, Poa alpina, Festuca kryloviana, Helictotrichon hookeri, Hordeum turkestanicum, Trisetum spicatum*
		Cryophytic meadows with *Waldheimia tridactylites, Cerastium lithospermifolium, Cysticorydalis fedtschenkoana, Allium carolinianum, Oxytropis albovillosa, O. chionobia, etc.*
	Mid-herb subalpine meadows	Forb-grass (*Festuca kryloviana, Alopecurus pratensis, Dactylis glomerata, Poa pratensis, Elytrigia repens, Phleum phleoides, Bromopsis inermis, Calamagrosris epigeios, Carex melanantha, Geranium collinum, G. saxatile, Allium hymenorhizum, Medicago tianschanica, Polygonum coriarium*, etc.
	Floodland meadows	Polydominant forb-grass and grass-forb meadows Grasses: *Alopecurus pratensis, Dactylis glomerata, Poa pratensis, P. angustifolia, Elytrigia repens, Phleum phleoides, Bromopsis inermis, Calamagrostis epigeios, Elymus caninus;* Forbs: *Carex melanantha, Geranium collinum, Allium hymenorhizum, Medicago tianschanica, Polygonum coriarium*
Savannoid	Low-herb savannoids of low mountain	Ephemer–sedge–bluegrass communities (*Poa bulbosa, Carex pachystilis, Phlomis salicifolia, Cousinia minkwitziae, C. micricarpa, Bromus lanceolatus, B. oxyodon*, etc.)
	Tall grass savannoids	Forb-grass, grass, shrub–forb-grass communities with prevailing ephemeroids (*Elytrigia trichophora, Hordeum bulbosum, Botriochloa ishaemum, Poa bulbosa, Carex pachystylis*) and communities of mesophylous and xeromesophylous geophytes (species of *Prangos, Ferula* genera)
Prick herb, thorn cushion (Phryganoid)	Prick herbs, thorn cushion (Phryganoid)	Communites of sclerophylous dwarf shrubs (*Onobrichis echidna, Acantholimon* spp.), dwarf semishrubs (*Artemisia* species) and perennial prick herbs (*Cousinia* species) with sinusions of meadow and cryophylous steppe plants

territories (Nature reserve Aksu-Jabagly, Sayram-Ugam National Park) the overall abundance of weeds and unpalatable species is observed, such as *Artemisia dracunculus, Rumex tianschanicus, Eremurus fuscus, Ligularia heterophylla*, etc.

1.6 Expected Impact of Climate Change on Plant Cover

Air temperature in Kazakhstan has been increasing steadily, on an average by 1.5°C, during the past five decades. The changes in the amount of precipitation are of an ambiguous nature. Climate change features in plains differ from those in mountains (Republic of Kazakhstan 2006).

Projections of climate change in Central Asia (temperature and rainfall) for the late twenty-first century (2071–2100) are suggested in the review by Ibatullin et al. (2009). The review was prepared accounting for two possible scenarios: A2 B2 greenhouse gases' concentration and based on four global climatic models (CSIRO2, CGCM2, HAD3, PCM). All the models and scenarios show that average annual and seasonal temperatures are expected to increase in Central Asian countries by the end of the twenty-first century. Reduction in rainfall during summers is expected, while winter precipitations will increase. According to the A2 scenario, in late twenty-first century, annual average temperature increase in Kazakhstan in different models will be from 3.3 to 6.7 °C in comparison with the basic period of 1960–1990. Annual average precipitation will increase by 27 %. According to the B2, which is more "mild," annual average temperature changes are expected to be less than 1 or 1.5 °C as compared with the A2 scenario. Changes in precipitation are within the same limits as in the A2 scenario.

Glaciers are one of the most sensitive indicators of climate change (Aizen et al. 1997; Republic of Kazakhstan 2006). Annual average temperature increase by 1°C during the recent century has resulted in a 30 % reduction in the south-eastern Kazakhstan glaciers (Republic of Kazakhstan 2006). Average rate of glaciers reduction from 1955 to 1990 is around 0.70 % per year. The process of glacier degradation will last for at least 80 or 100 years, then it will be followed by a new climatic cycle, which will be more favorable for development of glaciations (National Strategy 2001).

The latest investigations over the whole Tien Shan mountains based on remote sensing data have revealed that the numbers of glaciers are 7590, with a total area of 13,271.45 km^2 (Aizen et al. 2008). The main factor controlling the glacier regime in Tien Shan is the impact of air temperature that affects the type of precipitation, the duration, and the intensity of snow and ice melting throughout the altitudinal belts. The Tien Shan glaciers lost 8.5 % of their total area since 1970. The largest absolute as well as relative glacier area loss occurred in the northern Tien Shan (−361 km^2, 14.3 %), where the annual and seasonal sums of precipitation decreased at elevations above 3000 m (18.6 mm), and the summer air temperatures increased by 0.44 °C. The least absolute glacier recession has occurred in the western Tien Shan (−45 km^2), where summer air temperatures increased only by 0.23 °C and annual precipitation decreased by 13.4 mm. Glacier area change data are available for the western Tien Shan (−51 km^2, 29.8 %) from 1961 to 2000 (Konovalov, 2012). Tien Shan glaciers exist in arid continental climate only because of the spring–summer or summer maximum precipitation, which increase albedo in period of glacier melt. Therefore, even small decrease of precipitation along with increase of air temperature causes acceleration in Tien Shan glacier recession (Aizen 2011a). Glacier degradation rate depends on the size of glaciers, threshold area being 13–14 km^2. The regime of each glacier is particular. The territorial disparity of degradation rates is determined by the background air temperature, orographic conditions, relief, slope expositions, glacier morphology. Southern slope glaciers are less resistant (Republic of Kazakhstan 2006).

The latest studies in Altai-Sayan Mountains based on remote sensing data have recorded 2340 glaciers with a total area of 1562 km^2 (Surazakov et al. 2007). Between 1950 and 2000, Altai-Sayan glaciers have lost 14 % area. The accelerated glacier recession in Altai-Sayan Mountains is mainly due to the result of increased summer air temperatures by 1.03 °C in the past 50 years, which intensify the melting of glacier's (Aizen 2011b).

In order to estimate the recent changes of the southern Altai, north Tien Shan, and western Tien Shan range glacier areas within the territory of Kazakhstan, satellite images were chosen with spatial amplification (30 м)—Landsat ETM + Landsat OLI in the ablation period. The following combinations of spectral channels were used for the interpretation (http://gis-lab.info/qa/landsat-bandcomb.html): Landsat ETM +—5,3 wavelength Band 7 (1.55–1.75 nm), Band 3 RED (0.630–0.690 nm); Landsat OLI—7,4 wavelength Band 7 (2.1–2.3 nm), Band 4 (0.63–0.68 nm). Combinations of channels RGB—4,3,2 for Landsat ETM + and RGB—5,4,3 for Landsat OLI were used for data visualization. For a trustworthy identification and mapping of ice and snow we applied a normalized-difference snow index (NDSI). The borders of the open glacier part (pure ice and snow) are identified trustworthily from space satellite imagery. The borders of moraine formations were not accounted for, as their identification is not sufficiently trustworthy.

In 2000, the area of glaciers and snowfields in the southern Altai (Sarymsakty, Kurshum, Tarbagatai, south Altai ridges) made up 418.7 km^2, in 2013 it was only 228.8 km^2 (Fig. 1.2). Assessing the 13 years' dynamics, we can establish a recession of glaciers and snowfields by 190 km^2 (46 %).

Glacier and snowfield in the Kyrghyz Alatau (north Tien Shan) has recessed by 50 % during the recent 14 years (from 14 km^2 down to 7.1 km^2) (Fig. 1.3)

The area of glaciers and snowfields in the western Tien Shan (Ugam, Mayndantal, Talass Alatau ridges) in recent 11 years has increased by 17 % (it was 123.2 km^2 and is now 142.4 km^2 (Fig. 1.4).

The comparison of satellite images and calculation of areas has revealed the dynamics of glacier and snow cover changes during the recent decade. This process coincides with the general trends in the regions under study. The increased glacier areas in Kazakhstani west Tien Shan proves the statement concerning the ambiguous nature of the process and underlines the necessity of annual satellite and ground monitoring. Also, this may be connected with the fact that pure snow and ice are indentified en masse, therefore errors may occur in areas.

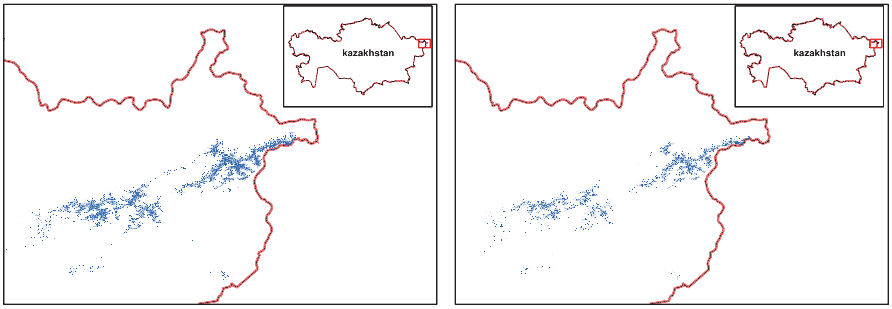

Fig. 1.2 Glacier and snowfield dynamics in the southern Altai

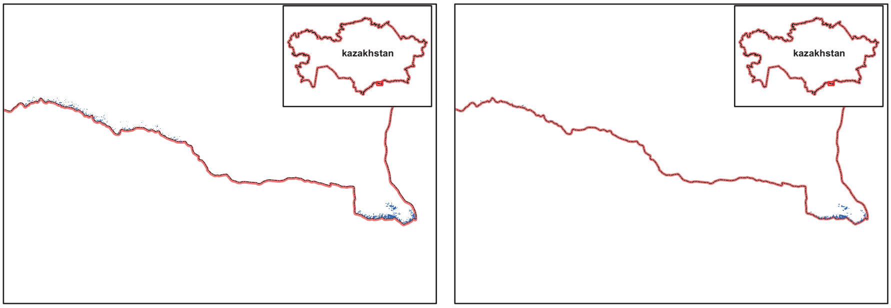

Fig. 1.3 Glacier and snowfield dynamics in the Kyrghyz Alatau

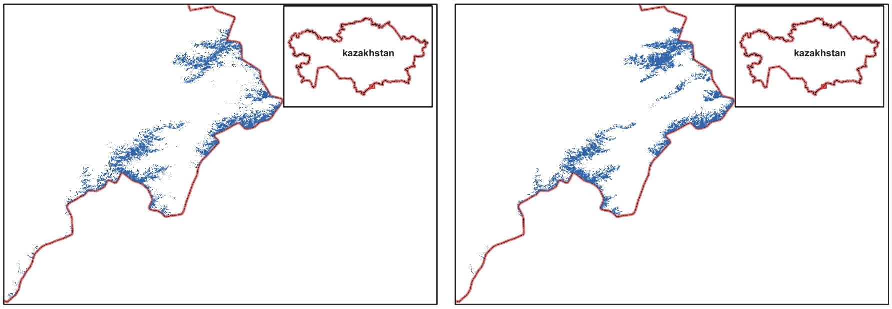

Fig. 1.4 Glacier and snowfield dynamics in the western Tien Shan

The studies of climate change impact upon the plant cover of Kazakhstan mountainous systems are in entry point. Recent publications by Proskuryakov (2010, 2012, 2013) pay much attention to chronobiological study of plants. Its principle consists in the establishment of monitoring facilities in the key sites for short-term (8–12 years) and long-term period (lifetime of plant cover dominants). Such a chronobiological study may include various indices: plant phenology, productivity, structure of plant populations, physiological, and biochemical processes. The original climatic background of each altitudinal belt varies in slope relief and correlation of warmth and moisture and solar radiation connected with the relief, which create a wide spectrum of plant habitats (Proskuryakov 2012). Chronobiological research in mountains is based on gradient study, drawing up empirical scales of quantitative features of distribution of the dominants depending on environmental condition. According to Proskuryakov, climate change still affects plants in a latent form, i.e., at the physiological, phenological, consortive levels. Thus, phenological study of Sievers apple tree (*Malus sieversii*) flowering at the lower border of wild fruit forests (800 m s.a.s.l.) since 1994 has illustrated the availability of two clearly expressed 6-year fluctuation cycles of apple flowering commencement date shift (Proskuryakov 2010). The first cycle—from 1998 to 2004. From 1998 to 2001, the flowering date shifted to the earlier stage by 16 days, then, from 2001 to 2004, the date had a shift to the later stage by 11 days. The latest flowering date at the absolute altitude of 800 ms corresponded to the flowering date for the absolute altitude of 1400 ms (Jangaliev 1977). The second cycle followed from 2004 to 2010, reveals that the flowering date first shifted to the earlier stage by 12 days; from 2007 to 2010 it again shifted to the later stage by 9 days. By the end of the 20 years' observations, the overall apple flowering shift to the earlier stage at the altitude of 800 m, overlapped the value of the whole amplitude of altitudinal belt variety of flowering commencement date within 1100–1800 m as of 1977. Thus, the observed apple flowering date shifts have resulted from the climate-induced deep internal changes in the life of plants. Many researchers observe the shifts of phenological dates (Zhou et al. 2001; Orlandi et al. 2005; Menzel et al. 2006; Chang et al. 2012; etc).

Plant species will respond to climate change in one of three possible ways: migrate to keep pace with climate change (but limited by habitat fragmentation, dispersal ability, and substrate requirements), adapt in situ through selection of tolerant traits, or become extinct (Aitken et al. 2008).

The studies in the southern Alps (Erschbamer et al. 2009) illustrate that even short-term (5 years) observations along the altitudinal gradient may reveal plant cover changes. It was noted that the species richness at the upper border of subalpine and alpine (sub-nival and nival) vegetation increased significantly, in the ecotone area of forest insignificant increase was marked. The changes can most likely be attributed to climate-warming effects and to competitive interactions. Species of the lower belts (mid-mountain forests) may penetrate into high-mountain belts. Such species may compete with the original plants and replace them at the account of shady and dense herbaceous cover. Endemic species of narrow habitats are especially vulnerable. Displacements of alpine species may be predicted for the near future. At the higher summits, expansions of the established alpine species and further invasions of species from lower altitudes are forecasted.

Accounting for the global climate change, the neighboring Republic of Kyrghyzstan has projected a shift in the environmental belts upward the mountain slopes (Titova 2002; Ionov 2003). The altitudinal belts of the mountainous systems bordering Kazakhstan will gradually move up. It is expected that the upper line of desert belt is going to rise by 200–400 m, steppe belt—by 200–250 m, forest and meadows—by 150 m, and subalpine belt—by 100 m (without changes in the Issyk-Kul depression). Desert landscapes will stay the same. In steppe belt that will replace meadow steppes and tall-herb meadows, savannoids will prevail: *Botriochloa ischaemum, Elytrigia trichophora, Inula grandis* as xerophyllous perennials of the late summer vegetation. Increased air temperature, sums of positive temperatures, vegetation period duration, and the amount of annual precipitation in steppe ecosystems will result in increased spring sinusium of ephemerals and ephemeroids, better productivity of desert and steppe communities. Significant changes might occur in the upper environmental belts. An intensive melting of glaciers will result in widened subalpine, alpine, and pre-glacier belts. High-mountain ecosystems of Kyrghyzstan will be dominated by xeromesophilic and xerophilic species. Many plant species, especially dominants, have natural adaptation features for surviving under new environmental conditions: a wide habitat and accommodation to the conditions of minimal rainfall amount and temperature contrasts. Increased air temperature, long summers, and the shift in vertical belts will not catastrophically affect the species diversity in the flora and vegetation. Many dominant plants have a wide environmental range and natural adaptation capacities. For instance, *Festuca valesiaca* grows in almost all the vertical belts of the mountains, prevails in plain steppe communities. This typically mesoxerophilous plant is highly resistant to extreme drought and trampling. *Dactylis glomerata* is a typical plant of meadows, including high-mountain and subalpine meadows. *Kobresia capilliformis, K. humilis* are dominants in alpine meadows, with wide habitat from Tibet to Tien Shan. All the vegetation types possess significant capacities: viable germs of plants, seeds, roots, bulbs, tubers that facilitate the accommodation to severe conditions. Mesophilous species receive a better development in humid years, the phytocoenotical role of xeromorphic plant species augments in droughty years. Rare, endemic, and threatened plants will be particularly vulnerable to the adverse effects of climate change, as well as plants and communities of a small environmental range (Uysal et al. 2011).

In Kazakhstan Mountains, altitudinal belt shifts are also expected. The fir belt will rise by 120–150 ms (The Second National Paper 2009). With global warming by 2–3°C, the steppe climate of the upper foothill level of Ile Alatau ridge (North Tien Shan) will be transformed into desert climate. Loess cover will disappear, foothills that currently are overgrown with herbs and shrubs will turn to badlands, involving the formation of catastrophic mudflows (Ibatullin et al. 2009).

Scenarios of future vegetation cover transformation will depend on the age of dominants in altitudinal belts. Fir age limit (*Picea schrenkiana*) reaches 500 years, tree juniper species live from 500 up to 800 years, climax communities will occupy their niches much longer than deciduous trees (*Malus sieversii, Armeniaca vulgaris, Crataegus* spp.), lifetime of which covers 100–150 years (Proskuryakov 2012).

A prediction of plant changes under new climatic conditions in the mountainous systems described in this chapter is based on the study of satellite images (Fig. 1.5). Plant cover dynamics has been identified from the same images which were used for the estimation of glacier and snowfields area changes. However, in plant cover studies we used the combination of spectral channels of Landsat ETM +—3,4 wavelength Band 3 RED (0.630–0.690 nm), Band 4 (0.75–0.90 nm); Landsat OLI—4,5 wavelength Band 4 (0.63–0.68 nm), Band 5 (0.845–0.885 nm). Different types of vegetation with their typical straight percentage cover and biomass possess certain spectral features in the visible and infrared ranges. Therefore, we used a soil-adjusted vegetation index (SAVI), which is well proven (Malakhov and Islamgulova 2014) even for the areas with sparse plant cover ($< 30\,\%$), typical of high mountain. To ensure a greater sensibility of the index in conditions of highland vegetation, we used in our estimations a correction factor 0.25.

BandMath mathematic operation tools were used for the calculation of index values of spectral brightness relations, and density slice function of ENVI 4.8 software was used to establish quantitative borders of separate classes; ArcGIS 10.1—for correcting administrative frontiers and for calculating areas. To assess the changes of plant spatial distribution, a digital model of relief was used as well.

According to the calculations, the reduction of glacier areas has taken place and a new substrate is formed for plant colonies, as well as expansion of the "sparse plant cover" class areas (Fig. 1.5). Each mountain ridge has its own scenario of ecosystem changes. The most severe plant transformation has taken place in Kyrghyz Alatau. During the recent 14 years, the plant cover has changed in the following way: the "sparse plant cover" class areas have expanded by 54 km^2 (Fig. 1.5), in water flows and canyons of various altitudinal belts a shear decrease in the straight percentage cover is noted. This testifies the aridization processes, which signifies that xeromorphic species will receive favorable conditions. Overgrowth is insignificant in the open surfaces exposed after the ice and snow reduction; ascension of plants to the next altitudinal level is not observed. It is still early to discuss the shifts of altitudinal belts. However, rangeland and hayfield productivity reduction is quite real.

A more favorable state of vegetation is typical in the western Tien Shan. Glacier area expansion has been observed. During the recent 11 years, the "sparse plant cover" class areas have expanded by 29 km^2 (Fig. 1.5). This has happened due to overgrown open surfaces not connected with glaciers and snowfields, as well as due to general aridization of plant cover and decrease in the straight percentage cover in the mid-mountain belt. In some places, plant aggregations rise averagely by 100 m.

In south Altai glacier area too, reduction is observed. The total area occupied by the "sparse plant cover" class areas has expanded by 97 km^2 in 13 years (Fig. (1.5). This happened due to the overgrowth of the exposed surfaces free from ice and snow. Thus, the altitudinal limit of the habitats of plants has ascended averagely by 200 m and in some places by 300 m. In other territories too, a reduction in the general plant abundance is noted in all the belts.

All the above data illustrate that the vegetation of mountain systems has undergone reconstruction. SAVI decreased index values are possibly connected with

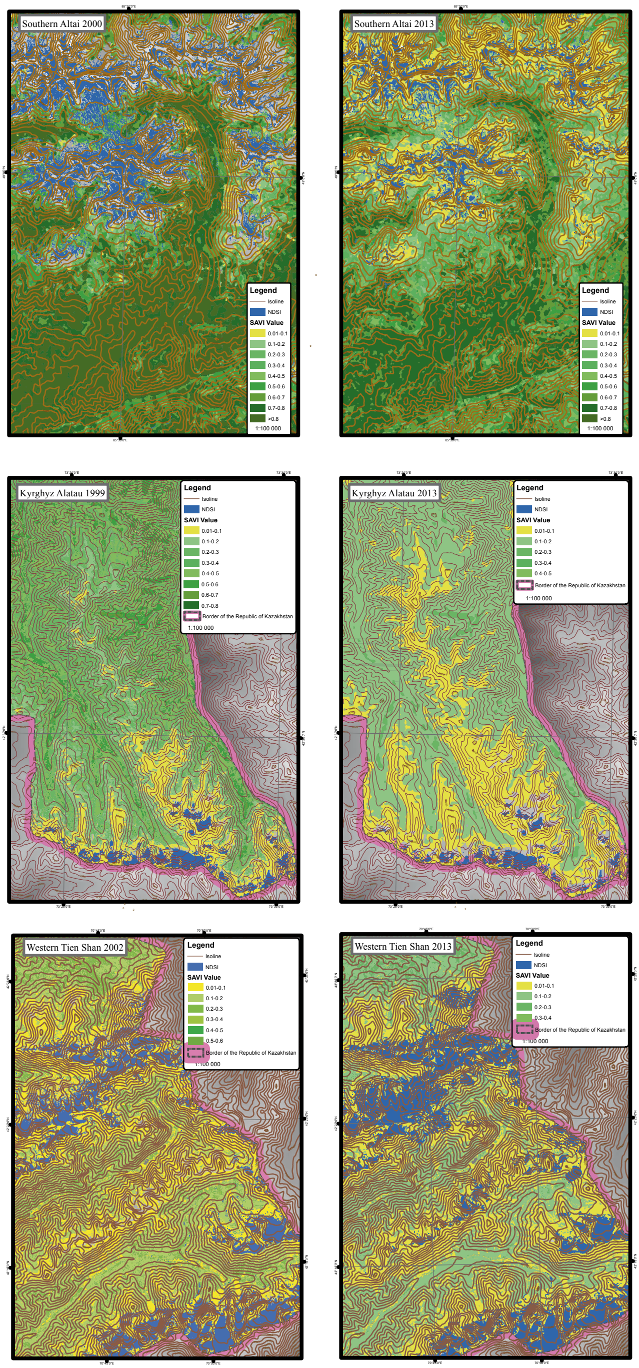

Fig. 1.5 Spectral features dynamics in the mountainous systems of Kazakhstan

ecosystem aridization resulting in less abundance of some species, reduced straight percentage vegetation cover and biomass. On the other hand, the reduced cover is possibly connected with changes in species composition, disappearance of one species and invasion by others. All these changes can be established only with the help of ground and space satellite monitoring.

Colonization of high-mountain plant groups has already commenced in the areas left exposed from glaciers. The species composition of such groups will aggregate in accordance with the environmental features and adaptive strategy of each species in each particular mountain range. In the high-mountain belt of Kyrghyz Alatau and western Tien Shan, rare and endemic plant species with a narrow environmental range occur which need a particular care.

Among these are: *Pseudoeremostachys sewertzowii, Juno orchioides, Allium talassicum, Primula minkwitziae, Scutellaria flabellulata, S. talassica, Polygonum coriarum, Oxytropis talassica, Scrophularia nuranii,* etc. The changes in the ecological condition may result in decreased number of plants in populations and disappearance threats. Wide environmental range species that are able to grow on mountainous meadow and meadow-steppe slopes, along river valleys, on gravelly and stony slopes, at the foot of glaciers and snowfields (*Festuca kryloviana, Helictotrichon shellianum, H. hookeri, Potentilla gelida, Artemisia aschurbajevii, A. rupestris, Omalotheca supina,* etc.) will migrate gradually, without species diversity losses. Species hybridization processes are observed in the southern Altai Mountain conditions (Kotukhov 1990).

Against the background of the general xerophytization of plant cover, rare, endemic, and threatened plants will be particularly vulnerable to the adverse effects of climate change, as well as plants and communities of a small environmental range. Species from the Red List do not always have narrow ecological niches; many of them reduce in number due to anthropogenic impacts. Therefore, protection activities would contribute to avoid their disappearance; still no protection can completely secure this.

Conclusions

Mountainous systems of Kazakhstan occupy less than 9 % of the country's area, but they embody over 60 % of Kazakhstan's plant species diversity. Being the centers of floristic genesis, mountainous ecosystems are characterized by a maximum accumulation of rare, endemic, and economically valuable species. There are centers on Kazakhstan's mountains which represent a unique genetic fund of agrobiological diversity as there are many wild relatives of different crops and fruit trees with their centre of origin lying here such as: apple trees, pears, blackcurrant, pistachio, almond trees, walnut trees, barley, alfalfa, liquorice, etc.

The information cited above has revealed a high plant diversity in the mountainous systems of Kazakhstan. A total of 2091 species of vascular plants grow in the southern Altai, 850 species in the Kyrghyz Alatau and 1491 species in the western

Tien Shan. The floras are rich in endemics; all of the ridges have narrow endemics not found in other regions. The traits of spatial plant distribution are unique as well as the features of altitudinal zonality. Each mountainous system has its own type of zonation. Common features of plant cover in combination with some dominant species are revealed in the mountainous belts. There are steppe representatives, such as *Festuca valesiaca, Stipa capillata, Helictotrichon schellianum, H. hookeri,* meadow—*Dactylis glomerata, Phleum phleoides, Hypericum perforatum,* shrubs—*Spiraea hypericifolia, Lonicera tatarica, L. microphylla*. Common signs peculiar to dominant arboreous species are found in the northern and western Tien Shan Mountains (*Juniperus semiglobosa, Betula tianschanica, Acer semenovii*). However, the species composition of plant communities is unique for each mountainous system.

Generally, there is an average degree of disturbance. In some places, severely degraded sites are found. The main factors of impact include grazing, haymaking, recreation, felling, and agriculture in foothills. During some decades human-induced impact has grown, which has already resulted in a considerable degradation of mountainous systems. In south Kazakhstan Mountains, juniper woodlands have perished because of soil pollution. Forest areas of east Kazakhstan have decreased as a result of unsustainable felling. Self-restoration of coniferous trees has almost stopped in the northern Tien Shan; advancing degradation of rangelands is increasing. Issues connected with recreation impact control are still underdeveloped. The experience of the alpine countries shows that the most efficient type of economic development of mountains is the combination of recreative and environmental policies (National Strategy 2001). There are nature-protected areas in the mountains of Kazakhstan: the Markakol Nature reserve and the Katon-Karagai National Park in the Southern Alatai, the Aksu-Jabagly Nature reserve, and the Sayram-Ugam National Park in the Western Tien Shan. There are no protected areas in the Kyrghyz Alatau ridge.

The plant cover of Kazakhstan's mountainous systems is double pressed under the conditions of the current global climate change. On one hand, there are man-made factors, on the other side changes provoked by the climatic background. Those changes show themselves already at the organismal level; phenological dates are shifting. The ecosystem level also undergoes transformation which can be seen on satellite images showing glacier melting, sparse plant groups growing in the places of former glaciers, and decrease of plant cover density in other altitudinal belts resulting from aridization.

A scientifically based action plan should be developed in order to safegaurd the vegetation of mountains and high-mountain plant communities in case of global warming. Such a plan should include (National Strategy 2001; Ionov 2003; Proskuryakov 2012):

- Drawing up a complete inventory of biological diversity and an assessment of its dynamical state.
- Conducting a cadastre of vegetation in the mountain regions.
- Establishing a system of protected areas aimed at biological diversity conservation.
- Conducting annual space and ground monitoring of the ecosystems.

- Realizing a chronobiological study of the basic species in the key sites.
- Developing actions for the restoration of the degraded ecosystems.
- In situ and ex situ conservation of rare and endemic species, wild relatives of crops and fruits trees.
- Sustainable use of the natural capacity of the biological and landscape diversity.
- Finally, introducing rotational grazing and haymaking, observing seasonality and multiplicity of the use of grasslands.

The observation of the dynamics of the basic ecosystem components in the structure of geoecological monitoring should be aimed at the identification of the main issues connected with the problems of mountainous areas, including biological diversity, climate change, and desertification. The priority segments of the structure would be monitoring of glaciers, water resource dynamics, and plant cover state. These environmental elements are the brightest indicators of the current geoecosystem transformations, including those provoked by the climate change.

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Chapter 2
Status of Natural Resources in the Uplands of the Swat Valley Pakistan

Habib Ahmad, Münir Öztürk, Waqar Ahmad and Shujaul Mulk Khan

2.1 Introduction

Swat is the focal point of the Hindu Kush Himalayan region of Pakistan and enjoys a central position in the trans-Hindu Kush Himalayan socioeconomic development activities. It is known for its natural beauty and some of the world's concerned biodiversity resources. It spreads over 8220 km^2 of land within 34°30′–3°55′ lat N and 71°45′–72°50′ E. The area can broadly be divided into three physical units, i.e., land, water, and biodiversity. A valley basin, largest among the valleys of the Hindu Kush, represents land of Swat. It is an eolian formation of the Cenozoic era and has highly interrupted the alluvial activities of Swat River. A single watershed of Swat River physically represents the area. The valley has altitudinal variations ranging from 600 m in the south to more than 6000 m in the northern high peaks, and the highest peak being that of Falaksair (6261 m). The area is mainly mountainous and rugged with a wide range of altitudinal variations, ranging from mild relief in the southern parts to very steep relief and high altitudes in the north (Jan and Mian 1971). The ridges are predominantly oriented in the north-south direction. Phytogeographically, most of the area of the valley comes under the Sino-Japanese region (Ali and Qaisar 1986; Ahmad and Sirajuddin 1996) with monsoon rains concentrated mostly in summer (Table 2.1), whereas toward the north (Swat Kohistan), the Irano-Turanian region dominates, having very little or no summer monsoon rains.

The word Swat, unless specified, is synonymously used for the area included in the Swat River catchment. The book introduces Swat in historical perspectives of the natural resources with special emphasis on the land, water, and biodiversity.

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Table 2.1 Meteorological data obtained from Agriculture Research Institute North Mingora. (Source: Khan and Khan 1993)

S. No.	Month	Temperature (°C)		Relative humidity (%)	Total rainfall (mm)	Wind velocity (km/h)
		Max.	Min.			
1	July	31.64	20.96	77.84	143.0	4.28
2	August	31.67	20.90	82.58	87.4	2.76
3	September	29.67	15.97	74.77	112.4	2.25
4	October	27.27	10.12	70.51	94.3	2.32
5	November	21.98	6.23	67.80	20.5	1.40
6	December	17.40	4.11	76.80	20.5	0.99
7	January	13.35	1.32	81.12	40.8	1.21
8	February	18.80	4.76	71.32	43.8	1.80
9	March	16.329	5.35	72.45	25.5	2.37
10	April	26.21	11.76	63.76	90.2	3.14
11	May	31.35	16.25	54.41	26.9	4.47
12	June	32.71	18.9	58.50	54.2	1.84
Monthly averages		24.86	11.39	71.16	64.64	2.4

2.2 Administrative Boundaries

The southern extreme of the valley comes under the administrative control of Malakand Agency and Dir district on the left and right banks of the Swat River, respectively. More than 87% of the area of the valley comes under the administrative control of Swat district. The area is bounded at all sides by the lofty Hindu Raj Mountains and is drained by a single watershed, i.e., the meandering river of Swat originating in the high mountains to the north >6000 m.

2.3 Population

Historical reviews supported by archeological evidence show that the Swat valley was inhabited by men in the prehistoric era between 2400 and 2100 BC (Ali and Khan 1991; Stacule 1969). It remained under the powerful domains of a variety of civilizations, the most prominent among which is the Gandhara civilization reported by the well-known Chinese travelers Fa Hien, Song Yun, Hiuen Tsang, and Wiking in the fifth to eighth century AD (Shah 1940; Hussain 1962; McMahon and Ramsay 1901). Fa Hien, who visited Swat area in AD 403, gave its name "Won-Chang" in Chinese, and "park" in English (McMahon and Ramsay 1901). He wrote that the language of the Swat people was similar to that spoken by the people in central India (McMahon and Ramsay 1901). Swat remained for more than 1000 years under Buddhist and Brahmin whose engravings are still preserved on rocks in various parts of the district.

Swat district occupies more than 87 % of the area included in the Swat valley. It has a population of more than 1.25 million individuals with a growth rate of 3.9 % and in migration of 3.2 %. Having been regarded as “an ideal place in summer for kings” (Khalil 1986), it is visited by thousands of tourists from the country and abroad. Its pleasing environment in the hot summer, the chilling water of river Swat, the scenic beauty of its landscape, and the widespread archeological sites provide much attraction to the tourists.

The district is inhabited by three ethnic groups (Barth 1956), i.e., Pathans, Gujars, and Kohistanis. Pathans, who are mainly Yousafzai by descent (McMahon and Ramsay 1901; Hussain 1962; Bellew 1994), depend mainly upon agriculture. They occupy plains, generally extending to a critical ecological threshold of supporting two crops per year. The climate of the valley is generally hot in summer. Vegetation in the area occupied by Pathans is highly degraded scrub.

Gujars, the Indian Aryans (Bowles 1977; Anonymous 1978), are the original inhabitants of the area (Bellew 1994). They generally use the foothills for agriculture and the highland meadows as grazing pastures. Though highly defused among Pathans, they exclusively occupy the mountain slopes and high-altitude areas. These areas comprise forests. The climate is cold, supporting monocrop agriculture at high altitudes of 1900 m and above.

Kohistanis are Dardic in origin (Barth 1956). They have been concentrated in the northern mountain gorges of Swat Kohistan. They mainly occupy areas beyond the reach of monsoon, generally of the subhumid to dry temperate zone. They practice both agriculture and livestock herding. Their area is cold and supports monocrop culture. Transhumance is observed in some of the highland Gujar and Kohistani tribes, whereas the tribal movements of Pathans (*garzenda wesh*) came to an end in 1932 (Barth 1995).

Both the Gujars and Kohistani are fluent in speaking Pukhto, the local Pathan language, besides their mother tongues, Gojri and Kohistani, respectively. Presently, the Swiss-sponsored “Kohistan Integrated Development Project” has greatly improved the Kohistani economy through the development of social organizations and the extension of improved agricultural technologies, especially the off-season vegetables culture. A sketch of the geographical boundaries of the valley is given in Fig. 2.1. Its geophysical and agroclimatic diversity supports the existence of wide variety of terrestrial and aquatic resources of wild and domesticated plants and animals. The area spreads over 8220 km^2 of land within 3430–3555°N and 7145–7250°E. Highly interrupted eolian deposits of Cenozoic origin mainly represent the basin of Swat valley. Its southern extremities come under the administrative control of Malakand Agency and District Dir on the left and right banks of the river Swat, respectively, whereas most of the area of the valley toward the north is included in the Swat district. The area is bound from all the sides by the lofty Hindu Raj Mountains and drained by a single watershed, i.e., the meandering river of Swat originating in the high mountains in the north. The flow of Swat River is mainly determined by the melting snow and ice from March to June and the incident monsoon rains in rest of the year, particularly in July and August. The valley has an altitudinal variation ranging from 600 m in the south to more than 6000 m

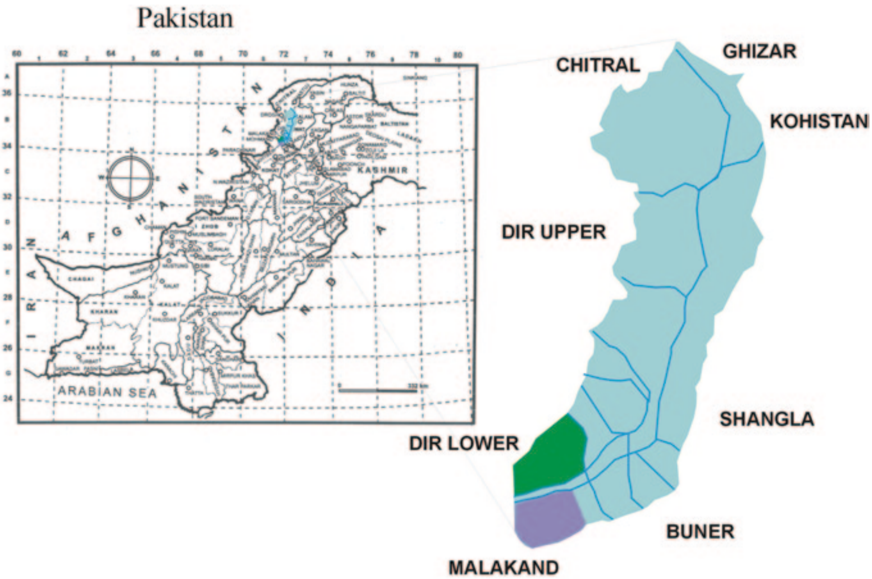

Fig. 2.1 Swat valley, location and administrative boundaries. (Ahmad and Ahmad 2003)

in the north. Mostly the area is rugged, with a wide range of altitudinal variation reaching upto 10,000 ft, within a small distance of 5 miles in the main ridges (Jan and Mian 1971). The ridges are predominantly oriented in the north-south direction. These highly varying topographic conditions affect the flow and thereby the lifestyle of the associated flora and fauna. Geoclimatologically, the Swat River falls under (1) monsoon excluding spating river ecology and (2) the monsoon prevailing sluggish river ecology. The former being restricted to the Kohistan region is represented by trout fish and can therefore be referred to as trout ecology. Whereas the latter that spreads over the entire river in the rest of the valley and is endemic to the *Schizothorax*-associated fish species and can be referred to as non-trout ecology.

Phytogeographically, most of the area of the valley comes under the Sino-Japanese region (Ali and Qaisar 1986; Ahmad and Sirajuddin 1996) with monsoon rains mostly in summer (Table 2.1), establishing a variety of biotic communities within the influence of various temperature and precipitation regimes.

For getting a broader overview of the impact and interaction among physical, chemical, and biological factors, secondary information are reviewed. Details regarding the secondary information is presented in "Reference" section of this chapter. Depending upon the variation in altitude, rainfall, and temperature regimes, the whole catchment is divided into:

- Lower Swat, starting just from Boosaq in the south and extends up to Nagova Spur in the north, prevailing generally over 600–900 m altitudinal ranges.
- Middle Swat, starting from Nagova Spur extending up to Shahgram in the north, generally having more than 900–1400 m altitude.
- Upper Swat, including areas with the altitudinal ranges generally exceeding 1200 m in the side valleys and 1400 m in the main valley of Swat.

- Swat Kohistan, having an altitudinal range of 1500–6000 m, within the prevailing subhumid to dry temperate type of climate.

Floristically, whole of the catchment is broadly divided into the artificial and natural type of forests. Further classification for each of these types is based upon the land-use system in the case of artificial forests and the evident climax vegetation in the case of natural forests. Climatically, the catchment was broadly divided into subtropical, temperate, alpine, and cold desert agroclimatic zones. The land-use system in each of these zones with regard to the cropping pattern, farming system, and the associated wildlife is discussed zone-wise. Direct field observations were made for recording floral and faunal diversity. Historical evidences with regard to the biodiversity situation were reviewed and the impacts of most important ecological factors on the biodiversity situation were elucidated. The direct and indirect role of a man, who is the highly skilled and most important among ecological factors, is also reported separately.

Ecologically, the Swat River was divided into "the torrent trout type" and "the sluggish non-trout type" of ecologies. Both the floral and faunal distribution in each ecological type is described separately. The role of Swat River as a resource base, for variety of socioeconomically productive systems of Khyber Pakhtunkhwa (KP), together with its role as a sink for absorbing and converting the household, agricultural, municipal, and industrial refuse into the precious bioproducts, is elucidated. For limnological aspects, the findings of Ahmad (1999) are reproduced as such.

2.4 Population and Ethnoecology

Historical reviews supported by the archeological evidence show that the valley of Swat was inhabited by men during the protohistoric era of 2400–2100 BC and remained under the powerful domains of variety of civilizations, the most prominent among which is the Gandhara civilization reported by the well-known Chinese travelers Fa Hien, Song Yun, Hsien Tsang, and Wiking in the fifth to eighth century AD (Shah 1940; Hussain 1962; McMahon and Ramsay 1901; Wylly 1998). Fa Hien, who visited Swat area in AD 403, reported its name as "Won-Chang" in Chinese, synonymous to "park" in English and "Udyana" in Sanskrit (McMhon and Ramsay 1901). He also reported that the language of the people of Swat was similar to that spoken by the people in central India (McMahon and Ramsay 1901). Swat remained for more than 1000 years under Buddhist and Brahmin maharajas whose engravings are still preserved on rocks in various parts of the valley. Presently, the area is occupied by more than 1.7 million individuals (Table 2.2), separated into three distinct ethnic groups (Barth 1956), i.e., Pathans, Gujars, and Kohistanis, exploiting different ecological niches and sharing the resources symbiotically. Pathans mainly depend upon agriculture and exploit the deep soil of the alluvial plains generally with irrigation systems. The climate in the plains is rather hot in summer, and generally, two crops a year are harvested from their fields. Vegetation of the Pathans exploiting ecology is generally scrubby.

Table 2.2 Population of Swat valley according to 1998 census

S. No.	Administrative unit	Population	Percentage
1	District Swat	1,249,572	72.03
2	Batkhela Tehsil	247,441	14.16
3	Chakdara Tehsil	235,920	13.80
Total		1,734,933	99.99

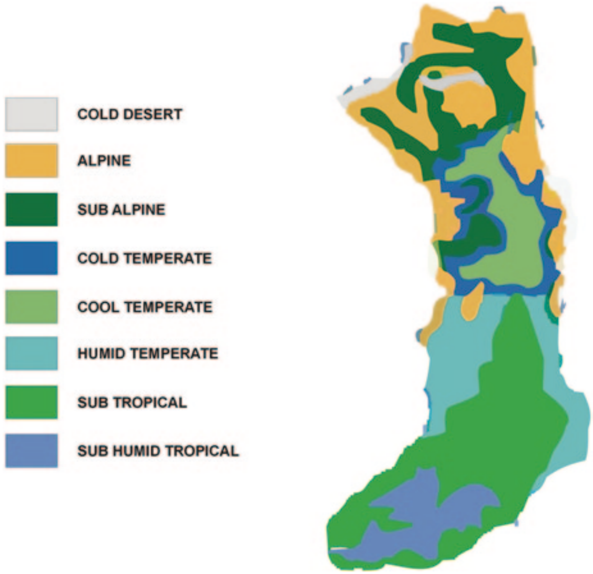

Fig. 2.2 A sketch of the major climatic zones in Swat valley

Gujars, though highly defused among Pathans, exclusively occupy the foothills and high-altitude areas. They practice both agriculture and livestock herding. They mostly comprise forest-associated communities and generally occupy colder climate, mostly supporting the monocrop culture.

Kohistanis are concentrated in the northern mountain gorges of Swat Kohistan. They mainly occupy the monsoon-excluded ecology of the subhumid to dry temperate nature. They practice both agriculture and livestock herding. Their area is too cold, and one crop in a year is generally cultivated. Presently, the Swiss-sponsored “Kohistan Integrated Development Project” has greatly improved the Kohistanis economy through social organization and the extension of the improved agricultural technology, especially through the introduction of the off-season vegetables in the area.

2.5 Geomorphology

The water into Swat River makes its way across a variety of geophysical formations. These formations not only affect the quality of its water and the associated life-forms but also determine the flow and speed of the river generally. The detailed geological surveys regarding the Swat valley show that various forces during the geological history have resulted in the formation of mountains, plains, and outwash deposits. A brief description of these landforms with special reference to its impact on Swat River is the content of this section.

2.5.1 Mountains

Most of the area of the Swat River catchment is mountainous, categorized into plutonic, sedimentary, volcanic, and metamorphic rocks. The subdivision of rock types commonly met within the area is presented in Table 2.3. It has the extreme relief of more than 10,000 ft in a horizontal distance of only 5 miles (Jan and Mian 1971) in the north and comparatively very mild relief in the south of the valley. The surface of mountains is generally rugged. In the northern part, natural vegetation covers most of the mountains that recharge the flow of local streams and ultimately the Swat River. The extinct of erosion is less here and therefore the turbidity and total

Table 2.3 Petrography of open rocks found in Swat. (Source: Jan and Mian 1971)

S. No.	Formation	Rock types	Probable period of origin
1	Dewangar, Matiltan, Lower Swat, and Malakand	Propyritic granite, granite, at places gneisses	Early to middle Tertiary
2	The Gabral plutonites	Quartz diorites, granites, and minor granodiorites	Early to middle Tertiary
3	The Deshai diorites	Quartz diorides, amphibolite, biotite gneisses, granites, and metagabbros	Early Tertiary
4	The Utrore volcanic	Sillicic to intermediate lavas ignimbrites, tuffs, and agglomerates	Cretopleocene
5	The Kohistan basic complex	Norites, diorites, bands of pyroxenites/anorthosites, granites, and minor amphibolites	Late Cretaceous
6	The Kalam group	Micaceous quartzites, siliceous schist, phyllite, siltstone shale, and limestone	Carboniferous to Siluro-Devonian
7	The Lower Swat, Buner Shiston group	Green schists, phyllitic schists, marble calcareous, and siliceous schists	Middle Paleozoic

dissolved solids (TDS) are very low. The natural forests have good humus and excellent fertility. Whereas in the lower valley (southern part), most of the forests have been uprooted and the mountains have lost the water-retention capacity. Runoff in monsoon rain therefore causes accelerated erosion and landslides and results in severe floods in the plains. It also contributes a variety of rock material and organic matters to the running water and therefore affects the quality of water recurrently.

2.5.2 The Outwash Deposits

Three types of depositions, i.e., colluvial, glacial, and alluvial recognized in the Swat River catchment area are described below.

2.5.2.1 Colluvial Deposits

These deposits resulted from the erosion and disintegration of rock surface. The rock particles of various sizes can be observed in this type of soil. It is generally highly drained and is not preferred for cultivation.

2.5.2.2 Alluvial Deposits

Generally, the deposition of gravels and fine rock materials under the influence of water results in alluvial deposits. The soil of this landform is generally coarse gravely to sandy loam with shallow or moderate depth. Most of the streambeds and their floodplains in the lower and southern parts of the valley are alluvial deposits.

2.5.2.3 Glacial Deposits

These landforms are established under the influence of avalanches. The moving glacier have brought and deposited a variety of organic and inorganic materials, including trees and boulders. The soils thus formed are generally unstratified and can very frequently be observed in the Kohistan area.

2.5.3 The Plains

Wind and water are the major factors responsible for the formation of plains in Swat valley. Four types of plains can be recognized here.

2.5.3.1 The Glacio-Alluvial Plains

These are the plains of minor extent and can only be observed in Swat Kohistan. They are generally formed by the joint activities of avalanches and water flow.

2.5.3.2 The Eolian Plains

These landforms represent the wind-borne deposits, of probably Cenozoic in origin. Its soil is characteristically very deep, fine-grained in texture, yellowish brown in color, and fertile in nature. Locally, this type of soil is referred to as *mata khawra*. Usually, this type of soil is free of gravels. This landform is heavily disrupted by the natural forces like the flow of water, glacial activity, and agricultural activities of men everywhere in the valley. Its uninterrupted pieces can only be observed along the mountain spurs downstream the river in the valley. It is susceptible to erosion and causes increased alkalinity and is the main source of inorganic suspended solids in the river water.

2.5.3.3 The Alluvial Plains

Alluvial soil is waterborne in origin, and its nature and composition is generally determined by rock type, the flow of water, and the distance of parent material from the parent rock to the deposition site.

Alluvial soil is generally shallow to moderately deep or deep over the gravel or stone beds, non-gravely and well drained. The relief of this landform is generally level to mildly undulating. Most of the floodplains of river Swat and its tributaries comprise this landform.

2.5.3.4 Eolio-Colluvial Plains

These land morphs are developed due to the transportation of eolian material through floodwater from one place and depositing it in another place. This type of soil, though quite deep in formation, cannot be stratified vertically. It is brown to dark brown in color, silty loam in texture, slightly alkaline, and represented by the rock material throughout the profile.

2.6 Agroecology and Farming Systems

The Swat River originates mainly in the alpine and flows within a variety of temperate and subtropical agroclimatic zones. A brief description of the zones recognized in the catchment (Table 2.4) is given below.

Table 2.4 Agroclimatic zones in the Swat River catchment. (Source: Ahmad and Ahmad 2003)

S. No.	Zone	Altitude (m)	Land use	Typical areas	Prominent features
1	Subtropical	600–1000	Double cropping, some tropical, and temperate fruits	Most of the area of Chakdara, Batkhela, and Barikot Tehsils	*Acacia modesta, Olea ferruginea,* and *Dodonaea*
2	Humid temperate	1000–1500	Double cropping, temperate fruits, and vegetable	Plains and foot-hills of Matta, Khwazakhela, and Charbagh Tehsils	*Pinus rox-berghii, Quer-cus incana,* and *Pistacia integerrima*
3	Cool temperate	1500–1900	Double cropping and some temper-ate fruits	The side valleys, e.g., Miandam, Malam, Sangar, Shawar, Sakhra, and Dabargi	*Pinus wallichi-ana* and *Quer-cus dilatata* prominent
4	Cold temperate	1900–2300	Monocropping of potato and maize	Upper limits of the side valleys, e.g., Mianbanr, Sulatnnr, Ushu, and Gabral	*Prunus cor-nuta, Aescu-lus indica,* and *Taxus wallichiana*
5	Subalpine	2300–3600	No agriculture, livestock graz-ing, and forest products	The high-altitude forests of Sham Sar, Spin Sar, Daral, and Ladoo	*Abies pin-drow, Picea smithiana,* and *Quercus semecarpifolia*
6	Alpine	3600–4600	Mainly used as grazing pastures and medicinal plants collection	The high-altitude meadows of Loi Pandghalae, Daral Sedgai, Boosaro Sar, and Gabhral	*Juniperus, Sib-baldia, Poten-tilla, Primulas,* and *Aconites*
7	Cold desert	4600–6000	Sources of peren-nial flow of the river Swat	High peaks of the Chitral adjoining areas, Falak Ser, and Mankial glaciers	Permafrost glaciers and ice caps

2.6.1 Subtropical Zone

Most of the plains in Lower Swat come under this category. It extends from 600 m in plains of Lower Swat upto 1000 m in plains of the Upper Swat. This zone comes under monsoon range and is characterized by mild winter (Table 2.5) with very little to no snowfall in winter, especially in its upper extremes. Summer is generally hot and humid. Tropical fruits like citrus, guava, mango, and banana can be cultivated here.

The prevalent farming system in this zone is cereal based; mainly rice and wheat is cultivated as kharif and rabi crops, respectively. Tobacco, onions, tomatoes,

Table 2.5 Meteorological data recorded in the subtropical zone

Month	Temperature (°C)				Rainfall (mm)	Humidity at	
	Mean daily		Extremes				
	Max.	Min.	Max.	Min.	Mean total	800 h	1700 h
January	14.7	0.8	20.6	10.0	66.0	84	58
February	17.5	2.5	23.9	−13.9	81.5	76	46
March	21.8	9.4	30.6	−4.0	115.6	74	48
April	28.8	13.8	33.0	0.0	59.7	60	36
May	35.1	19.4	38.1	3.9	13.0	48	30
June	38.0	21.7	41.5	8.3	7.1	43	25
July	36.1	23.8	37.7	11.1	80.3	62	45
August	34.1	23.2	37.4	7.9	87.9	77	59
September	33.8	20.1	33.9	3.3	35.3	73	52
October	30.2	13.8	32.2	0.1	12.2	64	39
November	23.6	7.7	28.0	−7.2	5.1	65	47
December	17.3	3.6	22.4	−9.4	18.8	77	52
Annual total	331.0	159.8	379.3	−9.9	582.2	803	537
Mean monthly	27.58	13.32	31.61	−0.83	48.54	66.92	44.75

citruses, and plums are the main cash crops. Turnip rape and lentil are the main rabi oilseed, and legume crops. Income sources like livestock keeping (mostly stalled buffaloes), fishing in the river network, and jobs in the government and nongovernmental organizations subsidize dependence on agriculture.

2.6.2 Temperate Zone

Temperate zone, which generally prefers the deciduous temperate fruits, is characterized by the prevalent winter snow. Depending upon precipitation, temperature, and altitude, this zone can be divided into the following types.

2.6.2.1 Humid Temperate Zone

Extending up to 1500 m in altitude in the main valley, this zone comes under the heavy summer monsoon rains and receives some snowfall in winter. Haronai valley in Upper Swat and the Swat River plain upto Fatehpur comes under this category. A hot humid summer hits the area generally in July but soon the whether becomes warm in August.

Temperate fruits, especially apples, are the most important crops of this farming system. Wheat, lentil, and turnip rape are the important cereal legumes and oilseeds of rabi, whereas maize and rice, black and green gram, and soya bean and sunflower are the major cereals, legumes, and oilseeds of the kharif. Onion agroforestry, peas, crucifers, and fruit plant nurseries are the internal parts of this farming system, besides livestock, particularly buffaloes.

2.6.2.2 Cool Temperate

This agroecological zone is spread over the side valleys and mountains of mid-altitudes extending upto 1900 m. Its typical examples are met within the habitats like Miandam, Malam Jaba, Peochar, Chail, Charma, Lalkoh, and Doughalgai areas. This zone gets considerable amount of snowfall in winter and heavy monsoon rains in summer. A short and warm summer prevails on this zone. It can generally be traced upto an altitude allowing double cropping system. Maize, potato, and wheat are the important crops of this zone. Buffaloes, cows, goats, and sheep herding is the integral part of this ecosystem. Here the landholding is generally small and the people suffice their livelihood through the products from natural forests.

2.6.2.3 Cold Temperate Zone

This zone occupies the altitude ranging from 1900 to 2300 m forming the dense forest. It can be observed in the areas of Sham Sar, Daral, Sedgai, and Ladoo areas. It occupies the last limit of blue pine and a mixed forest of yew, blue pine, horse chestnuts, bird's cherry, and some Himalayan elms. Forest products and grazing animals are the local practices observed in this agroecosystem. It is also exploited for monocrop agriculture of potatoes or maize.

2.6.2.4 Dry Temperate Zone

Basically, cold temperate in nature, it prevails on most of the area under Swat Kohistan. Areas included in this zone receive little summer monsoon rains and heavy snow in winter. This area comes under a short mild summer and permanent snow cover for up to 6 months in winter. It prefers single-crop culture. Potato or maize intermixed with beans and gourds are the common crops of this forming system. Recently, the off-season vegetable culture on commercial scale has improved the economy of the local people of this farming system. Cows, goats and sheep herding, and poultry rearing integrate the farming system in this area.

2.6.3 Subalpine Pastures

These are the high-altitude plains or south-facing screes, retaining snow for 5–6 months annually. But due to their topographic locations, it can grow bumper crops of potato or maize during the short summers. This type of temperate agroecologies where summer monsoon prevails, monocrop culture is visible upto an altitude of 2300–3600 m and can be observed in the high-altitude forests of Sham Sar, Spin Sar, Daral, and Ladoo. Herding livestock and forest products are the main economic activities of this farming system.

2.6.4 Alpine Zone

Alpine is the highest among agroecological regions of the Swat River catchment. The glacial lakes and a variety of beautiful plants represent it. The short summer, heavy winds, strong light, and little rains allow only highly reduced plants to perennate here. This agroecology can only be observed 3600–4600 m and can be easily seen in Spin Sar in Haronai catchment or Bosaro Sar in the Chail catchment, and Desan in Kohistan.

Crop cultivation is not feasible in the alpine. The alpine is mainly exploited for grazing livestock and the collection of medicinal plants, but only in the summer.

2.6.5 Cold Desert Zone

This ecological zone is represented by the highest peaks above the plant line and is marked by the presence of permafrost, ice fields, and glaciers. These habitats can be observed in the northern high mountains ranging from 4700 to 6261 m in Falakser, the high peaks of Chitral adjoining areas and Mankial series. This zone is solely responsible for the continued perennial flow of Swat River.

2.7 Phytogeography and Vegetation Types

Vegetation of the Swat valley can broadly be divided into artificial and natural type of forests. An overview of both of the types is presented bellow.

2.7.1 Artificial Forests

Man is inhibiting Swat back from thousands of years. Being dependent on the surrounding nature he has always interfered with the natural resources especially forests; either willingly or unwillingly, directly or indirectly, causing modification in floral composition through selective exploitation, replacement of species and introducing genetically uniform monoclones. The centuries old agriculture has resulted in domestication of new crop species, resulting in to two major types of overlapping artificial forests, i.e., cropland forest and agroforest. Each one of these is separately discussed bellow.

2.7.1.1 Cropland Forest

In Swat the cropland forest can broadly be divided into low-lying type and the monocrop type.

The Low-Lying Cropland

These croplands generally occur between 600 and 1600 m and sometimes even rising upto 1900 m of elevation, where two crops per year are harvested and are placed in the category of low-lying cropland forests. The area occupied by low-lying cropland forests is flat or with a mild relief. It enjoys sufficient irrigation and rains, having highly fertile soil. Two crops per year, i.e., rabi (early summer) and kharif (autumn), are grown here. In rabi, wheat is the commonly cultivated cereal, mostly cultivated on irrigated farms, whereas rapeseed and lens are the common oilseed and legume crops cultivated generally on the rain-fed fields. Barley, clover, oats, and *Lolium* are the important fodder cultivated as mixed crop in kharif fallow and irrigated fruit orchards. Peas, radish, cabbage, cauliflower, onion, and tomato are the important rabi vegetable. Rabi generally extends from November upto June. Kharif, which generally extends from July to October, is cultivated mainly for rice and maize as cereals. French bean, black gram, and green gram are the important kharif pulses. Soya bean and sunflower are the emerging oilseeds. Tomatoes, tobacco, pumpkins, gourds, melons, and okra are the important kharif cash crops.

The Monocrop Forest

Monocrop-type forest generally occurs above 1900 m and reaches upto 2700 m. It is generally established on the high slopes with colder climate. Here, one crop, either maize or potato, is cultivated; besides, some pulse legumes and vegetables are also grown as mixed crop. Recently, the successful introduction of the off-season vegetables in the monocrop ecology has boosted the socioeconomic situation of farmers in Swat.

2.7.1.2 Agroforestry

Agroforestry is a land-use system in which the woody perennials are integrated in the agricultural field for economical, social, or ecological purposes. Being highly productive system of sustainable agriculture, it has recently being established in the valley, though its species composition, genetic uniformity, and production capacity may vary from farmer to farmer and area to area. The production cycle and fluctuation in the market prices make it very difficult to classify the agroforestry systems. However, the general trend observed in the establishment of agroforestry can split it into the following types.

Expanding Fruit Orchards

Expansion in the area of fruit orchards is a general observation in plains. In Lower Swat, the cereal cultivated lands, particularly the rain-fed belt, are continuously shifting into the orchards of persimmons, peaches, apricots, plums, and citruses. The same type of land in the Upper Swat is shifted from cereal into apples, persimmons, peaches, plums, and cherries. If this trend continues, it will soon rise into the watershed and will help in conservation of soil and water resources greatly.

Agroforestry is economically the most important and highly preferred agricultural land use, though the detailed statistics of its by-products is not available. The agricultural statistics of NWFP (Abbasi 1996) shows that District Swat stands first in acreage, production per capita, and total fruit production among all the districts of NWFP. In Malakand Division, District Swat occupies more than double the area under fruit cultivation, among all the districts included in the division. It contributes more than 25 % share to the total fruit production of NWFP (Table 2.6).

Table 2.6 District-wise fruits production statistics of Malakand Division. (Source: Abbasi 1996)

			Name of the district				
S. No.	Item	Units	Buner	Chitral	Dir	Malakand	Swat
1	Total geographical area	$kilometer^2$	1843	14,850	5282	952	5102
2	Population	000, person	467	325	1412	440	1641
3	Area under fruits	000, hectare	0.13	0.41	1.63	0.93	6.16
4	Fruits production	000, tons	1.10	3.74	15.38	8.01	51.36
5	Yield per hectare	Kilograms	8462	9122	49.36	8613	83.38
6	Production per capita	Kilograms	2.36	11.51	10.89	18.20	31.30
7	Share in area to NWFP	Percent	0.53	1.68	6.68	3.81	25.26
8	Share in production to NWFP	Percent	0.46	1.57	6.46	3.36	21.56

Table 2.7 Area under commercial fruit orchards in Matta Tehsil during 1997

S. No.	Major fruits	Area under cultivation	Percentage
1	Apple	3404	83.63
2	Apricot	320	7.86
3	Persimmon	270	6.63
4	Plum	76	1.86

Matta Tehsil of District Swat, rightly termed as "Apple Tehsil," geographically located on 7215–7247°N and 3445–3415°E, occupies 66,580 ha of land with the altitudinal range of 1000–4080 m and a prevalent Himalayan moist temperate climate. More than 95 % of the apple production of Swat is harvested from Matta Tehsil. In Matta Tehsil, apple is cultivated on 83.63 % of the area under fruit crops. Other important fruit crops in terms of acreage are apricots, persimmons, and plums that represent 7.86, 6.63, and 1.86 %, respectively, of the area under fruits in Matta Tehsil (Table 2.7). Cherries and quinces are the emerging commercial fruits and could probably acquire an appreciable acreage with the passage of time.

Smallholder Plantations

Smallholder plantations are in general practice throughout the valley and are extensively observed in most of the farming systems in Upper Swat. In the hill farming system and floodplains, farmers generally spare the marginal lands for agroforestry, resulting in the establishment of a good riverian forest and small patches of subtropical and temperate forests giving some protection to the highly deteriorating representatives of biodiversity in the region.

Tree Integration on Farmlands

Tree integration on the farmlands is another beneficial practice carried out, especially for the purpose of fruits, fuelwood, fodder, and timber demands. In this type of agroforestry, the trees are generally planted on the field boundaries; on the one hand, it gives protection to the crop field, and on the other hand, its economic utilization adds significantly to the farmer's economy. The linear plantation on the orchard boundaries is also a common practice, though this practice has multiple benefits of protection of fodder, fuelwood, and timber and its role in soil fertility through nitrogen-fixing trees. Still this practice has some negative effect, i.e., for example, shading effect, allelopathy, competition, etc. pronounced particularly in the small farms. In some cases, the boundary trees of the neighboring fields drastically affect the cereal yield.

The boundary trees are generally more efficient competitors for space, nutrient uptake, and water absorption, as compared to the fruit trees planted inside the orchards. They generally hamper the bearing, particularly in the small orchards, where the number of boundary trees generally exceeds more than the fruit trees inside the orchard.

Shade Belts

Shade belts (*Soorae, Goodarae,* and *Damazae*) present near the community places and meadows add a little to the area under agroforestry and the community environment in particular. But it has a vital role in introduction and maintenance of the exotic species besides the natural vegetation.

2.7.2 Natural Forests

Phytogeographically, most of the area of the valley comes under Sino-Japanese region. It enjoys plentiful precipitation in the form of monsoon rains. Whereas the northern parts of the valley with marginal summer monsoon and heavy snowfall in winter come under the Irano-Turanian region. The area has established the west Himalayan moist temperate and dry temperate forests in the respective phytoecological regions. Though it is mainly the altitude and rainfall which broadly determine vegetation and general ecology of the area, the effect of exposure, topography, and biotic pressure, especially the interaction of man, have prominent role in determining floral composition and overall physiognomy of the forest locally. In the recent past, whole of the Swat River catchment was densely covered with wetlands, subtropical, temperate, and alpine forest, which remained exposed to the excessive human activities, resulting in to croplands or denuded ruderals with the passage of time, and population growth.

Practically, 95 % of the wetlands have been transformed into croplands. Most of the area under subtropical forests was either converted into cropland of limited floral diversity and genetically uniform stocks. Or its unwise use turned it into highly degraded wastelands. In temperate forests, generally established on the high mountain slopes, wherever terracing was feasible, the forest was uprooted and turned into cropland. The unwise human practices led to accelerated erosion on the one hand, but on the other hand, the recharge capabilities of springs and their depending have generally checked everywhere, especially in highly destroyed subtropical watersheds. The only forest which remained protected in the catchment is the iron oak- and birch-associated forest (2500–3800 m) which can only be observed in the high-altitude ranges of Upper Swat and Swat Kohistan.

Various vegetation types and their floral composition, mainly based upon the prominent climax flora (irrespective of their aspection), are discussed here in the ascending order of altitude considerations.

2.7.2.1 Karr Vegetation (Riverbed Artemisia Scrub)

Karr locally referred to the floodplains, which are highly prone to the frequent floods. It develops highly variable vegetation in spring, mainly due to the transported plant propagules from the high altitudes of the catchment. Permanent feature of the Karr vegetation comprises *Artemisia scoparia, Saccharum spontaneum, Desmostachya bipinnata, Debregeasia hypoleuca, Datisca cannabina, Lotus corniculatus and species of Hypericum, Astragalus*, etc.

2.7.2.2 Subtropical Forest

Subtropical forests are the low-lying highly degraded forests, which rise up to 1500 m in the main valley and can be observed from Malakand Hills in the southern extreme up to Shahgram in the north. Three zones of highly degraded subtropical forests are visible in the valley. A brief description of each is given below.

Acacia–Reptonia Forests

These forests can be established on the southern and eastern faces of the hills mostly up to 1000 m. It can be observed on the roadside hillslopes from Dadhara down to Qalangai. The differentiating feature of this forest is *Acacia modesta* associated with *Reptonia buxifolia. Dodonaea vesica, Ficus glomerata*, and *Bauhinia variegata* also associate the main features in this zone. Shrubs like *Adhatoda vesica,* Ziziphus *numularia, Rhazya stricta, Gymnosporia royleana, Carrisa ophaca, Ehretia obtusifolia, Otostagia limbata, Woodfordia fruticosa, Periploca aphylla*, and *Nannorrhops ritchieana* are also observed in this zone. Due to easy access and high dependency level, most of the forests of this zone have been uprooted. Only its remnants are visible in Malakand, Adinzai, Abakhel, and Shamozai hills. A better patch of this type of forest can be observed in Pirkhel forest near Mekhband.

Acacia–Olea Forests

This zone is also delimited to the main valley and extends up to 900 m. Most of the denuded slopes of the catchment were once covered with this type of forests. The prominent feature of this forest *is Acacia modesta, Olea ferruginea,* and *Dodonaea vesica*. Other associated species include *Zanthoxylum armatum, Mallotus philippensis, Punica granatum, Pistacia integerrima,* etc. *Litsea* spp., *Pavetta tomentosa*, and *Quercus glauca* may be also observed in southern parts of these forests. Bushes of *Rubus* and *Adhatoda vesica, Ziziphus numularia, Rhazya stricta, Gymnosporia royleana, Ehretia obtusifolia, Otostagia limbata, Woodfordia fruticosa,* and *Periploca aphylla* are common. The regenerating patches can be observed in protected places like Nawab Abad (3 km north of Matta Town on the main road) and Pirkhel forests near Mikh Band and Zalam Kot in Malakand Agency.

Subtropical Chir Pine Forest

The prominent feature of these forests is the evergreen chir pine *(Pinus roxberghii*). It can be seen in a degraded form in the low-lying mountains of Malakand, Moura, Elum, and Laram. It generally rises up to 1500 m or sometimes more as in Shamirae (Tirat). Other associated species are *Quercus incana, Pyrus pahsia, Pistacia integerrima, Rhododendron arboreum, Rosa moschata, Isodon rugosus, Indigofera heterantha, Berberis lycium, Woodfordia floribunda, Rubus fruticosus*, and *R. ellipticus*. On the southern faces of Nepkikhel mountains, the chir pine is generally associated with the dry oak, i.e., *Quercus baloot.*

2.7.2.3 Temperate Forests

The temperate forests in Swat valley can be divided into moist and dry temperate forests.

Moist Temperate Forests

Moist temperate vegetation of Swat is represented by the low-lying oak forests, blue pine forests, fir and spruce forests, and the timberline oak forests.

The Low-Lying Oak Forest

These forests mainly form the dense vegetation of lower hills and were established on the mountain slopes in the Upper Swat. These forests have the pure stand of *Q. incana* generally on the northeastern faces in the deep rich soil. *Quercus dilatata* occupy the same altitudinal range and may rise further high and generally prefer the south and eastern faces. Still they are present in a degraded form in monsoon-prevailing moist mountain terrain of Matta, Khwazakhela, Kabal, and Charbagh Tehsils. Other associated species of these forests are *Pinus wallichiana, Olea ferruginea, Diospyros lotus,* and *Pistacia integerrima*.

In the depression and watercourses of these forests, *Alnus nitida, Salix tetrasperma, Ficus palmata* and *Salix babylonica* are the common species, whereas *Platanus orientalis, Morus alba,* and *Melia azedarach* are also found but generally in the cultivated form. Among the subflora, species like *Berbaris lyceum, Rubus fruticosus, Isodon rogosus, and Rosa brunonii* are frequent. Herb of the genera like *Impatiens, Viola, Polygonum, Potentilla*, and *Geranium* and members of *Graminae* along with the species of ferns, mosses, and liverworts represented the ground flora.

These forests are the main and easy source of subsistence for the local communities in the form of timber, fuelwood, torchwood, fodder, and medicinal and cash herb for the past 30 years. Most of these forests were generally uprooted for agricultural cultivation or burnt for fodder and forage production.

The low-lying oak forests are nowadays becoming rare in the area. They are only preserved in sacred groove or on the land under personal protection. These forests were the main recharge sources of springs and thereby the feeding streams of Swat River. Their uprooting has not only impaired the general environmental health but also deteriorated the breeding sites of migratory fishes.

Blue Pine Forest

These forests are established on the upper limits of low-lying oak forests and were exclusively formed by a single dominant conifer, i.e., *Pinus wallichiana,* with a close canopy. It also has localized distribution of *Parrotiopsis jacquemontiana* and *Juglans regia* forests in the northern slopes. These forests can be observed in pure stand in almost all of the catchment area in between 1500 and 2500 m.

Subflora in this forest comprises the species of *Sarcococca saligna, Indigofera heterantha, Berberis lyceum, Buxus wallichiana, Rubus niveus,* and *Rubus fruticosus* in the lower limits, and species of *Salix, Parrotiopsis jacquemontiana, Viburnum foetens,* and *Skimmia laureola* in the upper limits.

In summer, the forest floor is decorated by the lush green cover of graminaceous herb associated with the species of *Ranunculus, Potentilla, Fragaria, Atropa, Rumex,* and a variety of ferns. *Hedera helix* and *Rosa brunonii* are the common epiphyte and climber, respectively. These forests provide habitat to a number of cash plants like *Morchella, Pteris, Viola odorata, Viola kashmiriana, Adiantum* spp., *Fragaria vesica, Atropa acuminata,* and *Phytolacca*, etc.

These forests are under severe biotic pressure; approximately, one-third area of the blue pine forest have been cleared in the past three decades, while the forest cover in the remaining half is left nearly 50 %.

Fir and Spruce Forests

These forests have been established in the upper mountain limits and constitute a dense forest adjacent to the tree line. A very beautiful stand of these forests can be observed around the villages Sulatanr, Miabanr, and Qadar. These forests extend from 2500 to 3000 m; predominantly, spruce (*Picea smithiana*) and fir (*Abies pindrow*) occupy the southern drier faces and northern misty faces in the same altitudinal ranges. Yew (*Taxus wallichiana*) also associates these forests at their lower limits. Blue pine and *Quercus semecarpifolia* also contribute to the forest stand in its lower and upper limits, respectively. Other broad-leaved deciduous trees sparsely distributed in these forests are *Aesculus indica, Prunus cornuta, Salix* spp., *Ulmus wallichiana,* and *Betula utilis,* etc. These forests have a dense subflora in the deep moist soils comprising the species of *Viburnum foetens, Salix* spp., *Indigofera* spp., *Desmodium podocarpum, D. tiliaefolium,* and *Aralia cachemirica*, and *Sorbaria* *tomentosa* and herbs like *Sambucus wightiana, Arisaema jacquemontii, Arisaema tortuosum, Rumex nepalensis, Plantago major*, and *Taraxacum wallichii*.

These forests provide habitat for a variety of fruits and culinary, aromatic, medicinal herb; besides the timber and non-timber forest species, these forest also provide shelter for a wide variety of wild animals, including pheasants, snow leopards, and bears.

Tree Line Oak Forests

These forests occupy the tree line (2900–3700 m) and are mainly composed of iron oaks (*Quercus semecarpifolia*), associated with the sparse distribution of *Picea smithiana* and *Betula utilis*. The subflora in these forests is generally like that of fir and spruce forest, including dense vegetation of *Viburnum foetens* and species of *Salix*. Edible ferns are of considerable economic values, which flourish, in early summer, in these forests. The open glacial areas bloom with the species of *Taraxicum, Plantago, Impatiens, Potentilla, Ranunculus, Sambucus, Thymus,* and *Rumex*. Beautiful cobra plants and giant snails are of particular interest of this ecosystem. These forests are established on a narrow belt but hav remain intact due to its inaccessibility and comparatively little economic use of *Q. semecarpifolia*.

Dry Temperate Forests

In the monsoon-excluded region of Kohistan, the vegetation is represented by *Quercus ballota* and associated vegetation. Here the blue pine (*Pinus wallichiana)* is replaced with *Cedrus deodara*. *Pinus gerardiana* associates deodar. On the roadside, it can be seen in mixed stand opposite to Peshmal and can frequently in the Utrore valley. The timberline vegetation of dry temperate forest mainly comprises *Betula utilis*.

2.7.3 Alpine Scrub

This vegetation type can easily be observed in Spin Sar, Boosaro Sar, Loi Pandghalae, Desan, and Falak Ser surrounded areas. Scrubs of *Juniperus communis* are present in patches on rocks, whereas the deep soils are generally dominated by the species of *Sibbaldia cuneata* and *Rumex,* associated with patches of *Senecio chrysanthemoides*, *Aster*, *Euphorbia wallichii, Sambucus wightiana*, *Corydalis govaniana, Thymus linearis, Iris hookariana, Plantigo himaliaica, Geranium collinum, Anemone, Potentila*, and *Polygonum*.

These scrubs possess best grazing potentials and feed thousands of livestock in the summer months. Overgrazing is the strongest biotic factor associated with the deterioration of the subalpine. Most of the plants are seriously exposed to overgrazing. Junipers inhabiting the area are shrinking both in terms of area and cover due to trampling and its use as the only easily available fuelwood in the alpine. All these and other associated factors have caused severe erosion, which can easily be observed on most of the slopes in alpine.

2.7.4 Alpine Pastures

These are the highest occurring vegetation in the area and can be examined all around the Shago Sarookai, Mankial, and Falak Ser (4600–6000 m). Most of the plants inhabiting this area are herbaceous with a very strong subterranean parenting systems and wide range of pleasing colorful flowers, which always bless the tourist's mind and welcome the grazing animals. It provides grazing pastures to thousands of livestock visiting in the month of July–September every year.

Floristically, the area is represented by the species of *Sibbaldia cuneata, Trollius acaule, Bergenia stracheyi, Potentilla pamiroalaica, P. peduncularis, P. astrosanguinea, Geum elatum, Rhodiola himalayensis, Polygonum viviparum, Viola kashmiriana, Primula denticulata, Primula macrophylla. P. ellipticaa, Plantigo himalayca, Corydalis diphylla*, a species of *Rhododendron,* few edible ferns, and a fair distribution of *Aconitum violaceum*.

2.8 Biodiversity Situation

Neither a complete record of biodiversity of the area exists nor a taxon-wise complete census of floral and faunal composition, along with genetic diversity, comes under the scope of this chapter. However, an effort has been made to elaborate the biodiversity composition of the area based on some authentic literature and my personal observation regarding the area, for the past 30 years. Biodiversity has been very broadly divided into floral and faunal diversity below.

2.8.1 Floral Diversity

Floral diversity is broadly divided into domesticated/introduced and endemic types. The domesticated or introduced floral diversity includes various agricultural crops. More than 66 species (with a wide range of genetic diversity in each) are cultivated in the area, which can be split into nine types of commodities as given in Table 2.8.

Agricultural extension, generally carried out on the fertile lands, has resulted in the creation of homogenous artificial plant assemblages, with high genetic uniformity and low floral diversity. It has generally brought modification of natural

Table 2.8 Species diversity of crop plants commonly cultivated in Swat. (Source: Ahmad and Sirajuddin (1996))

S. No.	Commodities	No. of species
1	Cereal	04
2	Oilseed	07
3	Pulse/legume	07
4	Fruits	20
5	Vegetable	20
6	Condiments	05
7	Fodder	04
8	Starch	02
9	Fiber	01
Total		*66*

species composition and their assemblage. Hence, it may be concluded that the extension of agriculture has delimited the natural species and genetic diversity, especially in the plains and specifically in the wetland. Only 66 species of agricultural or horticultural crops are cultivated in fields.

Available data regarding the natural flora of the area shows that it include 1473 species of angiosperms. Among which 311 are monocots and 1162 being dicots. Ferns identified are 55 and gymnosperms being 13 species. Division-wise breakup of some of the plant species is given in Table 2.9.

Most of these plant resources had its specific and general uses locally and were being exploited and managed through the traditional ways in the past. Economic use of some of the plant resources is given in Appendix. Though no baseline is present on the frequency and cover of biodiversity of the area, visual observation shows that most of the floral diversity is under stress. The stress varies from place to place depending upon access and need of the users, ecological amplitude of the species, habitats losses, palatability of species, regeneration capacity, and limits of tolerance of the species. Some of the important species, which are under severe stress, are given in Table 2.10.

Table 2.9 Species diversity of natural floral recorded from Swat

S. No.	Division	Families	Species	Source
1	Pteridophyta	06	55	Stewart 1967
2	Gymnosperm	03	13	Stewart 1967
3	Monocots	20	311	Stewart 1967
4	Dicots	106	1162	Stewart 1967
5	Diatoms	–	116	Shah 1992

Table 2.10 Some plant species with high ecological stresses

S. No.	Species	Local name	Cause of degeneration
1	*Carex indica*	Taspa bootai	Habitat loss
2	*Reptonia buxifolia*	Gwargwara	overuse
3	*Ehretia obtusiloba*	–	overuse
4	*Litsea monopetala*	Meda chob	Over collection
5	*Quercus glauca*	Banojai	overuse
6	*Colchicum luteum*	Soranjan talkh	Over collection
7	*Acorus calamus*	Skhawaja	Habitat loss
8	*Ulmus chumlia*	Kahae	Habitat loss
9	*Aesculus indica*	Jawaz	Overuse
10	*Podophyllum emodi*	Gangora	Overuse
11	*Acer caesium*	Shin lakhta	Habitat loss
12	*Acer cappadocium*	Tarkana	Habitat loss
13	*Aconitum violaceum*	The ghra zahar Zahar	Over collection
14	*Prunus cornuta*	Changa	Habitat loss

2.8.2 Faunal Diversity

Like plants, no baseline data exists on animal diversity at species or genetic level. However, some historical reports elaborate the situation of biodiversity very well. Khushal Khan Khattak, the celebrated Pashtun poet, visited this area in the seventeenth century AD; his views (Khalil 1986) and feelings regarding the biodiversity of Swat can be elaborated from the following stanzas.

Translation

- Every year, 200–300 very beautiful best quality falcons are trapped in Swat.
- Second, the country has plentiful chackor partridges to be preyed everywhere.
- Waterfowls are found everywhere in Swat River, which are ruthlessly shot by the inefficient locals.
- Three types of ibex and one markhor are severely exposed to shooting locally.

The spontaneous increase in human population associated with the unwise use of natural resources resulted in habitat loss and deterioration of trophic level and food chains, which not only threatened the availability of certain economically important wildlife but also made the existence of other living species impossible. Presently, even a single falcon cannot be trapped per year by hundreds of hunters waiting painfully (for months) in the high mountain ranges. The presence of ibex and markhor remained only a theoretical consideration on the lower reaches. The incidence of chackor partridge and waterfowl has become very rare. They are generally shot in the air and the unchecked shotguns hurt before their landing. It is the broader outlook of the wildlife in the area. Still a number of resident and migratory birds, mammals, and reptiles can be observed in the area of river Swat catchment. A summary of the important animal life in the area is given below.

Among mammals, snow leopard may be traced in the northern glaciated alpines. Musk dear, markhors, hare, and Himalayan ibex can only be recorded in the tree line birch forests. Black and brown bears of limited incidence can also be observed in the tree line iron oaks and birch forests. Snow cock, snow partridge, monal and koklass pheasants, and gorals, which were common three to four decades back, have become rare. All these animals generally prefer the areas raising more than 2500 m in altitude. Monkeys are still of common incidence in high mountain ranges. Hyenas, jackals, leopards, pigs, porcupines, hares, jungle cats, and hedgehogs are still there but of rare incidence. Other birds like finches, warblers, chats, tirts, yellow beak, and a number of pigeons are found here.

The low-lying mountains and the valley basin, which are easily accessible, are mostly exposed and have highly exploited ecology in the catchment and have a variety of faunal distributions. Black and gray partridges are still found here on the hillside. Many kinds of ducks, waders, white-cheeked bulbuls, paradise flycatcher, rufous-backed shrike, black drongo, and ringdoves and quail also visit the valley. Paradise flycatchers, once common, have diminished with the diminishing natural forests.

Among reptiles, *Diadema, Ladacensis, Mucosus, Ventrimaxulatus,* and *Zamenis* are fairly distributed. Cobras and crates generally prefer the rain-fed plains, whereas vipers can generally be found in the stony floodplains of the Swat River. Lizards of various kinds are found frequently. The most prominent among reptiles is the innocent *Veranus* spp., which grows more than a meter in length. Other animals like jackals, porcupines, and foxes are the common inhabitants of colian cliffs. Goral and Kabul markhor, which were once common, can only be traced in the difficult rocks of Elum, Morah, and Malakand series.

Among resident bird fauna of the valley, house crow, house sparrow, red-vented bulbuls, common myna, rufous-backed shrike, egrets, common kingfisher, white-breasted kingfisher, black tits, crested lark, and black partridges are mostly visible. The migratory birds which visit this area include black drongo, Brahminy myna, paradise flycatcher, house swift, wall creeper, warblers, wagtails, and babblers.

The wildlife in Swat is mostly under threat of unawareness of the local communities, leading to the excessive hunting and poaching, habituat losses due to agricultural extension and forest cutting, unchecked tourism, and pollution of water bodies.

2.9 Avian Fauna

The valley of Swat supports a number of bird species. Unfortunately, very little is known regarding the bird's fauna of Swat. The only birds which are generally referred in the literature are the pheasants and partridges. Other birds have received no attention. Depending upon the migratory behavior, bird's fauna in Swat can be divided in to resident and migratory types; each one are discussed separately.

Table 2.11 Some of the resident bird species of Swat valley

S. No.	Scientific name	Common name	Local name
1	*Acridotheres fuscus*	Common myna	Kharo
2	*Alectoris chukar*	Chakor	Zarka
3	*Alcedo atthis*	Common kingfisher	Shin kwanae
4	*Ammoperdix griseogularis*	See-see	Se-sai
5	*Ceryle rudis*	Pied kingfisher	Kirkirak
6	*Corvus splendens*	House crow	Qargha
7	*Francolinus francolinus*	Black partridge	Taro
8	*Francolinus pondicerianus*	Gray partridge	Tanzarae
9	*Halcyon smyrnensis*	White-breasted kingfisher	Kirkirak
10	*Lanius schach*	Bay-backed shrike	Teghak
11	*Lerwa lerwa*	Snow partridge	Warookay goria
12	*Lophophorus impejanus*	Monal pheasant	Lait
13	*Lophora leucomelaena*	Kaleej pheasant	Zangaly charg
14	*Passer domesticus*	House sparrow	Chanchanra
15	*Pucrasia macrolopha*	Koklass pheasant	Baiger
16	*Pycnonotus cafer*	Red-vented bulbul	Balbala
17	*Pycnonotus leucogenys*	White-cheeked bulbul	Balbala
18	*Streptopelia decaocto*	Collared dove	Korkorai kaotra
19	*Tettaogallus himalayensis*	Snow cock	Goria
20	*Turdoides caudatus*	Common babbler	Sourae
21	*Upupa epops*	Hoopoe	Mula chargak

2.9.1 The Resident Fauna

The species living throughout the year in a particular area are referred to as the resident species. The common resident species in Swat are presented in Table 2.11.

2.9.2 The Migratory Birds Fauna

Some of the birds visit the catchment during their breeding season, and they either come to the valley for breeding or pass through it between their breeding and wintering grounds. A list of the migratory birds generally observed in Swat is given in Table 2.12.

Variety of birds like brown dipper, Ned starts, robins, thrushes, a large number of waterfowls, and waders pass through the valley unknown and still unclassified, which needs to be identified and their status conferred as resident or migratory.

Table 2.12 Migratory birds generally observed in Swat

S. No.	Scientific name	Common name	Local name
1	*Anas acuta*	Pintail	Tarlakay
2	*Anas crecca*	Common teal	Kach shingharae
3	*Anas platyrhynchos*	Mallard	Shin satay
4	*Anas querquedula*	Shoveller	Plan makhokay
5	*Aythya ferina*	Common pochard	Soor sarai
6	*Carpodacus erythrinus*	Common rosefinch	Sper sarai
7	*Coracias benghalensis*	Indian roller	Shintagh
8	*Coturnix coromandelica*	Rain quail	Nwaraz
9	*Dicaeum erythrorhynchos*	Tickell's flower-pecker	Chatae
10	*Dicrurus caerulescens*	Black drongo	Toranraka
11	*Galerida cristata*	Crested lark	Khrara
12	*Gallinago gallinago*	Common snipe	Chaghat
13	*Himantopus himantopus*	Stilt	Chaghat
14	*Hirundo rustica*	Common swallow	Totakarkay
15	*Motacilla alba*	White wagtail	Speerlakay
16	*Motacilla citreola*	Yellow-headed wagtail	Zairaqa
17	*Motacilla flava*	Yellow wagtail	Zairaqa
18	*Motacilla maderaspatensis*	Large pied wagtail	Speerlakay
19	*Oriolus oriolus*	Golden oriole	Pilaoroo
20	*Pericrocotus flammeus*	Scarlet minivet	Liala majnoon
21	*Phipaiura aureola*	White-breasted fantail	Teghstargai
22	*Phylloscopus collybita*	Brown chiffchaff	Tarae
23	*Prinia criniger*	Brow hill warbler	Chatae
24	*Seicerus xantroschistos*	Gray-headed flycatcher	Chatae
25	*Sturnus pagodarum*	Brahminy myna	Jabanai kharo
26	*Sturnus vulgaris*	Common starling	Sakhaka
27	*Tersiphore paradise*	Paradise flycatcher	Poonai

2.10 The Swat River

Swat River is the only drainage basin of Swat valley. It originates in the form of rushing perennial streams of the permanent ice caps and glacial lakes in the lofty mountain ranges in the north extremes of the Swat valley. These streams soon unite to form Gabral River and Ushu Gol in the northern valleys of Gabral and Mahodand, respectively. Both of these rivers flow southwards and, after covering a distance of 35–40 km in their respective valleys, join at Kalam, giving rise to the Swat River.

The Swat River flows in a narrow gorge from Kalam to Shagram in an average course of 35–40 m. Though the gorge is last at Shagram, the narrow course of the river continues upto Talapanr. Hereafter, the river spreads upto 400 m in majority of location across the course, in the valley. In the extreme south of the valley, the meandering river once again inters into a narrow gorge and joins with the Panjkora River at Boosaq/Sharshamai.

Ecologically speaking, the whole freshwater network of Swat can be split in to:

- The monsoon-excluded spating river ecology.
- The monsoon-prevailing sluggish river ecology.

The monsoon-excluded *spating river ecology*, being restricted to Swat Kohistan, is represented by the torrent cold water. Trouts prefer the rushing cold water ecosystems like the streams and rivers in Kohistan. It is therefore referred to as the trout ecology.

The torrent water currents do not allow angiosperms to be established in the riverbed. The adjoining moist rocks, however, develop a variety of hepatics, mosses, ferns, and cyanophytes. Among angiosperms, horse chestnuts, bird's cherry, maples, *Diospyros,* and poplars are the prominent trees. Deodar, spruce, blue pine, yew, and fir are the common conifers of the slopes.

The monsoon-prevailing *sluggish river ecology,* which spreads over the river in the rest of the valley, particularly in the Lower Swat, is characterized by the cold water with rather sluggish movement. This ecosystem is predominantly occupied by the *Schizothorax*-associated fish species and is not visited by the trouts. It can therefore be referred to as non-trout ecology.

Diverse types of the cyanophytes, chlorophytes, bacillarophytes, lower embryophytes, and tracheophytes inhabit the river and its tributaries. They not only provide oxygen for the submerged life but also maintain equilibrium in the ecosystem. Common among the hydrophytic trees are populus and willows below 1000 m, and adlers and willows are more common above 1000 m. Adlers are nitrogen fixing in nature, adding much to the fertility of soil and nitrogen content of water generally.

2.10.1 Tributaries of Swat River

Precipitation in the form of rain and snow is the main source of water recharge of Swat River. Most of its water makes their way to Swat River, either through direct runoff, melting snow, or seepage and leeching. Though the direct seepage contributes much to the permanent streams and Swat River, these are generally the tributaries which affect the flow, quality, and productivity of the Swat River. Though a large number of seasonal and perennial tributaries contribute to the river, only those tributaries which apparently contribute to the perennial flow of Swat River are described below.

2.10.1.1 Gahil Stream

Downstream, Kalam, the Gahil Stream, is the first large water body which significantly contributes to the flow discharge of Swat River. It emerges in the lofty glaciers of Gahil catchment, providing best site for trout feeding.

2.10.1.2 The Mankial Stream

A perennial stream emerges into the eastnorthern glaciated peaks of the valley and combines with the river Swat near Mankial. The stream has cold water and favors the habitat for trout.

2.10.1.3 Daral River

Daral River is mainly fed by the glacial lakes of Daral and Tarkana located in the western boundaries in between Swat and Dir Kohistan. Its rushing water contributes much to the flow of the Swat River. It joins Swat River on its right bank at the Behrain Town. Its cold rushing water also favors the trout community.

2.10.1.4 Chail Khwar

It originates in the Chail, Beshigram, and Dabargai catchment at the northeastern extreme of the Upper Swat. Chail Khawar joins Swat River on its left bank at Madyan. The stream water is fit for trout culture and feed a number of trout commercial hatcheries established in its basin.

2.10.1.5 Bawari Khwar

It originates in Sakhra catchment and joins Swat River at Kalakot. The stream bares warm water, having mild flow, and the land is rich in organic contents. It prefers warmwater fish and is inhibited by a number of *Schizothorax* species.

2.10.1.6 Haronai River

It originates in Spin Sar at the right side alpine of the catchment and is fed by an area of 46,425 ha. It contributes much to the flow of Swat River and serves as the largest spawning ground for *Schizothorax* and mahseer. It joins Swat River on its right bank near Koza Bamakhela.

2.10.1.7 Manglawar Khwar

It originates in the moist temperate forest of Manglawar catchment. It contributes a little to Swat River, particularly in the winter months. It also serves as a breeding site for *Schizothorax* and mahseer.

2.10.1.8 Jambel Khwar

It originates in the northern face of Mount Elum. On reaching Mingora and Saidu Sharif territories, it becomes highly contaminated with fecal derivatives and industrial and household pollutants, though most of its water is used for irrigation crops. Its filtered seepage again adds to its flow, but the pollutant concentration is so much that it enters Swat River in the form of a dead water body. The stream serves only as a contamination source for the fecal and other noxious substances to the river.

A large number of streams in the Lower Swat, Swat Ranizai, and Adinzai, which were contributing much to the flow of Swat River in the recent past, remained no more productive. It is due to the fact that their catchment has lost the vegetation cover, mainly responsible for conservation of water and the recharge of these streams. The streams are there and serve as drainage basins of monsoon flood.

Limnology

Detailed limnological studies of Swat valley (Ahmad 1999) revealed that the temperature, pH, alkalinity, and hardness of water, whatsoever its source may be, are in the normal potability. Conductivity, which is the measure of mineral contents, everywhere in Swat, is under the permissible limits. Total solid (TS) content of the main river is also within the normal range of potability, whereas in tributaries, the content of TS was generally high, still falling under the maximum limits of potability (Table 2.16).

Total suspended solids generally crossed the normal range of potability, i.e., 30 mg/mL. Its maximum quantity (1000 mg/L) was recorded in the sample collected from Daral Khwar, which might be as a result of the accelerated erosion of rock material due to the high water speed. The TDS were maximum in Barwai Khwar, i.e., 480 mg/L, which comes under the normal limits of drinking water.

Dissolved oxygen, which determines the health and self-purifying capacity of water body, was lowest in Jambil Khwar, i.e., 5.9 mg/L still high than the minimum required limits (5 mg/L) of WHO. Biological oxygen demand (BOD), which is directly proportional to the quantity of oxidizable organic matter, remained under the normal limits (7.5 mg/L) downstream upto Mingora, but at once reaches to 11.6 mg/L at Panjigram after receiving the polluted water of Jambil Khawr. This situation is gradually improved downstream at Gammon Pul and Pul Chwakai, where the quantity of BOD recorded was 9.6 and 5.86 mg/L, respectively. Chemical oxygen demand is a very useful tool for the determination of the quantity of domestic waste in a water body. In Swat River and its tributaries, its value was higher than the normal acceptable limits. Similarly, ammonia determines the quantity of organic pollutants. The concentration of ammonia falls under the acceptable range for Swat River downstream till Mingora, but the addition of effluents from Mingora municipality crosses the acceptable limit of 2.00 mg/L. The nitrite content in all the samples except that collected from Jambil Khwar (12.09 mg/L) proved within the normal range of potability, whereas the concentration of nitrates in all the water bodies was within the acceptable limits of water quality.

Concentration of chlorides and phosphates proved lower, whereas the sulfide contents in all the samples were higher than the WHO standards. Furthermore, the concentration of sulfates was higher than the potable limits, except in the water collected from Jambil Khwar, where it was 330 mg/L, showing the large-scale addition of domestic waste into the water body (Table 2.13).

Among metals, the concentration of sodium, copper, and potassium was generally within the acceptable limits of potability in all the waters. The concentration of potassium in the water of Jambil Khwar and that of cadmium and lead generally exceeded the normal range of potability (Table 2.14).

The *Escherichia coli* counts, which directly determine the fecal contamination of water, were proved to be the level of intermediate risk value at up- and downstream Kalam. While rest of the sampling areas of Swat River and its tributaries were at high risk of fecal contamination, the water of Jambil Khwar proved to be at the very-high-risk level and is therefore not fit for drinking.

2.11 Algal Flora

Microorganisms inhabit a variety of ecological conditions mostly due to their interspecific and intraspecific diversity, enormous numbers, plasticity, and wide ecological amplitudes. They serve both as producers and decomposers, making essential balance in the aquatic ecosystem and food chains, though there is generally a dearth of knowledge regarding the microflora of Swat River. However, the important algal flora reported from the ecosystem is presented in Table 2.9.

2.12 Ecology of Swat River

Depending upon the river flow, climatic conditions, and availability of fish fauna, Swat River network ecologically can be divided in to two types, i.e., the trout and non-trout ecologies.

2.12.1 Trout Ecology

This zoosociological region can be restricted to Swat River and its tributaries occurring in Swat Kohistan and is extended upto Talapanr during winter and colder months of the year. Most of this area do not receive summer monsoon rains and is therefore dry in summer. In winters, most of the precipitation occurring here is in the form of snow.

Due to lack of summer monsoon, the river do not face the recurrent flood situation. Here water temperature rarely exceeds 20 °C in the month of July. The river flows in the narrow gorge in a deep basin of 35–40 m width. The little exposed area

Table 2.13 Chemical characterization of water from Swat River and its tributaries. (Source: Ahmad 1999)

S. No.	Place	Water body	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NO_3+N (mg/L)	NO_2+N (mg/L)	NH_3+N (mg/L)	S (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	CL (mg/L)
1	Kalam Bridge	Swat River	9.6	1.34	25.0	0.10	1.130	1.34	0.80	88.71	2.34	15.90
2	Peshmal Bridge	Swat River	9.6	2.80	15.0	1.80	1.801	2.80	1.76	76.50	1.57	14.90
3	Bahrain	Tributary	9.8	2.66	15.0	0.20	1.609	2.66	0.80	73.84	9.65	8.90
4	Madyan Hatchery	Tributary	10	3.34	15.0	1.10	0.696	3.24	2.40	36.62	8.62	9.90
5	Ranzra Pul	Swat River	9.65	2.54	5.0	0.60	2.953	2.54	1.70	68.36	1.67	9.90
6	Rahat Kot Bridge	Tributary	7.4	3.48	5.0	1.50	3.565	3.48	0.80	59.0	5.65	5.60
7	Bama Khlea	Swat River	6.2	2.54	15.0	0.80	2.913	2.54	2.40	98.88	9.32	20.80
8	Matta Bridge	Tributary	6.9	2.00	5.0	0.60	3.697	2.00	1.60	92.77	10.85	8.90
9	Kuladher Bridge	Tributary	5.9	6.94	45.0	1.60	12.09	11.60	12.29	330	10.17	21.80
10	Punjiram	Swat River	7	1160	25.0	0.60	2.478	0.94	0.70	89.11	12.71	10.90
11	Grammon Bridge	Swat River	6.9	9.60	5.0	0.60	1.130	9.60	2.40	88.71	11.67	6.90
12	Pul Chaukai	Swat River	7.1	5.86	12.0	0.70	3.565	5.86	0.90	96.84	10.34	10.90

BOD biological oxygen demand, *COD* chemical oxygen demand, *DO* dissolved oxygen

Table 2.14 Concentration of some metals in the water of Swat River and its tributaries. (Source: Ahmad 1999)

S. No.	Place	Water body	Sodium (mg/L)	Potassium (mg/L)	Copper (mg/L)	Cadmium (mg/L)	Lead (mg/L)
1	Kalam Bridge	Swat River	2.44	0.1608	0.2	0.3	0.8
2	Peshmal Bridge	Swat River	2	0.108	0.06	0.132	0.08
3	Bahrain	Tributary	0.88	0.56	0.08	0.08	0.06
4	Madyan Hatchery	Tributary	0.64	0.8	0.06	0.1	0.2
5	Ranzra Pul	Swat River	4	0.106	0.04	0.04	0.2
6	Rahat Kot Bridge	Tributary	1.5	3	0.04	0.04	0.14
7	Bama Khlea	Swat River	2.412	1.6	0.04	0.06	0.1
8	Matta Bridge	Tributary	2.32	6.3	0.04	0.06	0.12
9	Kuladher Bridge	Tributary	8	24.12	0.06	0.04	0.2
10	Punjiram	Swat River	2.44	2.2	0.08	0.04	0.16
11	Grammon Bridge	Swat River	1.28	1.7	0.06	0.08	0.26
12	Pul Chaukai	Swat River	1.7	2.2	0.04	0.04	0.12

Table 2.15 Expected risk situation in river Swat and its tributaries. (Source: Ahmad 1999)

S. No.	Place	Water body	Lead (mg/L)
1	Kalam Bridge	Swat River	17
2	Peshmal Bridge	Swat River	45
3	Bahrain	Tributary	150
4	Madyan Hatchery	Tributary	35
5	Ranzra Pul	Swat River	350
6	Rahat Kot Bridge	Tributary	550
7	Bama Khlea	Swat River	–
8	Matta Bridge	Tributary	–
9	Kuladher Bridge	Tributary	1800+
10	Punjiram	Swat River	900
11	Grammon Bridge	Swat River	275
12	Pul Chaukai	Swat River	550

Table 2.16 Physical characterization of the water of Swat River and its tributaries. (Source: Ahmad 1999)

S. No.	Place	Water body	Temp. (°C)	PH	Cond. (µg/cm)	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	ALK (mg/L)	HAD (mg/L)
1	Kalam Bridge	Swat River	10	7.81	37.6	400	60.0	340	5.00	12.0
2	Peshmal Bridge	Swat River	10	7.90	35.2	200	40.0	160	7.00	12.0
3	Bahrain	Tributary	11	7.90	20.0	1000	580	420	6.50	9.0
4	Madyan Hatchery	Tributary	11	8.23	37.5	600	280	320	5.00	10.0
5	Ranzra Pul	Swat River	10	7.08	35.8	400	200	200	4.00	12.0
6	Rahat Kot Bridge	Tributary	17	7.56	40.7	800	320	480	7.00	23.0
7	Bama Khlea	Swat River	11	7.92	40.2	580	320	260	5.00	10.0
8	Matta Bridge	Tributary	19	7.98	195.1	240	140	100	9.00	40.0
9	Kuladher Bridge	Tributary	20	7.71	310	600	200	120	14.00	61.0
10	Punjiram	Swat River	14	8.07	67.6	300	80	400	5.00	25.0
11	Grammon Bridge	Swat River	14	8.17	54.7	600	140	460	5.00	12.0
12	Pul Chaukai	Swat River	14	7.26	55.8	200	80	120	5.00	11.0

ALK alkalinity, HAD *hardness*, *TDS* total dissolved solids, *TS* total solids, *TSS* total suspended solids of water from the melting snow and its high speed retains the temperature throughout similar. This area is dominated by the carnivore fish, i.e., trout.

2.12.2 Non-Trout Ecology

This zoosocialogical region extends downstream Talapanr Bridge and spreads over the rest of the Swat River and its tributaries in Upper Swat, Swat, Ranizai, and Adinzai sections of the valley. This area gets through monsoon rains both in summer and winter. In monsoon season, its discharge increases, which is temporary and for short duration. Similarly, in summer, the increase in daily temperature increases snow melt and causes rise in flow everywhere in the perennial streams and Swat River.

The monsoon rains generally results in heavy floods, causing damage to agricultural crops generally. This region is represented by the meandering shallow flow. Its speed becomes mild, and due to a wide exposed area of shallow water, its temperature increases downstream. *Schizothorax* spp. generally prefers this ecology. In summer, warmwater fishes like mahseer from the river Kabul visit this ecology. The river also serves as breeding site for mahseer.

2.12.3 Fish Fauna of Swat River

Fish, the divine gift and most precious among water resources, serves as a major economic activity in rural communities, particularly to the people settled near the river basin. Though the adverse role of human beings in polluting water with organic, inorganic, and biological wastes caused eutrophication in certain cases and brought changes in the floral and faunal composition of water body. Yet these are the electric current, dynamiting, and poisoning, which are becoming threat to the existence of the fisheries. These malpracticing have severally deteriorated the aquatic fauna severely, particularly in the tributaries. If this trend is not checked, it appears that some of the endemic fishes will become extinct soon.

Swat River is represented by a variety of fishes (Butt 1986), among which *Slam* turtle (brown trout) and *S. qaridneri* (rainbow trout) were introduced here in 1928 and 1973, respectively. Their lethal temperature starts from 23 °C upward (Aston and Brown 1978) and hence can only be found in the river and its tributaries occurring in Swat Kohistan.

Tor putitora (Mahseer, Zegai) is the warmwater fish found in the Lower Swat area. Due to its diminishing population, resulting mainly from scarcity of spawning grounds and malpracticing prey, it seldom appears in the market.

Three species of snow trouts which can tolerate temperatures below 8–22 °C (Mirza 1976), viz., *Schizottorax esocinus, Schizothorax richardsonii, Plagiostonus*, and *S. progostus labiatus* are the common delicious Swati fishes. *Garra gotyla* (Deq) are the most common warmwater fishes and can frequently be found particu-

Table 2.17 Incidence of the common fishes in Swat River

S. No.	Species	Incidence (%)
1	*Schizothorax-richardsonii-plagiostomus*	26.13
2	*S. progastus-labiatus*	3.97
3	*S. esocinus*	2.84
4	*Salmo-gairdnerii*	3.97
5	*S. trutta-fario*	2.27
6	*Channa-punctatua*	7.95
7	*Mastacembelus-aromatus*	2.27
8	*Shistura-alepidotus-alepidotus*	1.70
9	*Triplophysa-grifthii-naziri*	7.95
10	*T. stenurus-choprai*	4.54
11	*Crassocheilus-diplocheilus*	3.40
12	*Puntius-ticto*	6.81
13	*Barilius-vagra-pakistanicus*	10.12
14	*Tor-putitora*	10.22
15	*Garra-gotyla*	3.97
16	Glyptothorax-stocki	5.11
17	*Glyptosternum-reticulatum*	2.84

larly in the streams. They become very frequent in the months of May and June. Other frequent fishes are *Triplophysa naziri* (Singi) and *T. choprai*. *Glyptosternum reticutatum, Schizothorax bruclii, Schstura alepidotua,* and *S. naseemi* can commonly be seen in Swat. The incidence of various types of fishes in Swat River is given in Table 2.17.

Chakdara is the only fish reserve in which mainly *Schizothorax, Tor,* and *Cyprinus* (paplate) are the most popular fishes of this reserve. The reserve is established to provide safe ground to the local fish resources. Legally, no fishing is allowed in the reserve area, but the rules cannot strictly be observed due to vested interests of powerful elite class, sharply unmarked boundaries of the reserves, and inadequate monitoring of the staff.

2.13 Man as an Ecological Factor

Man is the most powerful and highly organized ecological factor who interacts with the natural resources directly or indirectly, and willingly or unwillingly. His curses for getting more have disrupted every natural balance globally. On Swat River, the influence man is both direct and indirect, which are discussed as below.

2.13.1 Direct Impact

2.13.1.1 Water Pollution

Most of the settlements established on or near the river dispose their solid and liquid wastes directly to the river. This careless addition cause fecal contamination and increased TS of water, resulting in lowering water quality; with the increased potability risk (Ahmad 1999), water pollution is a problem everywhere in Swat valley, and most of the diseases prevalent here are waterborne in nature.

2.13.1.2 Eutrophication

Eutrophication is a situation when the release of phosphates and nitrates or organic matter in to the water body reaches to such an extent that oxygen level in the water drops, resulting in an evident change in faunal composition of the water body. The apparently eutrophicated water bodies are the Jambel, Thana, and Chakdara streams. The farmer has very high BOD (Ahmad 1999), whereas for the latter, its value is unknown. BOD is actually a standard for determining the oxygen requirement of a water body, or it is used to measure the rate at which the oxygen level of a sealed sample of the water falls when kept in dark for 5 days at 20 °C. The BOD of unpolluted river water is typically less than 5 mg O_2/L/days.

2.13.1.3 Heavy Metal Toxicity

Most of the industrial (particularly the cosmetics) and automobile wastes add nickel, lead, mercury, selenium, and zinc to the water, which certainly cause toxicity. The unplanned growth of industries into workshops and service station on the riverside needs to be checked; otherwise, both their vertical and horizontal growth will cause deterioration of Swat River. Similarly, wastes from the marble industry and that of the emerald mine contribute significantly to alkaline pollution of water in Swat River.

2.13.1.4 The Loss of Wetlands

Wetlands which were once spreading all over the length of Swat River and its tributaries have been converted to agricultural fields. These wetlands not only provided spawning sites to most of the fishes but were also used as resting grounds for a variety of migratory birds. Besides all these, the wetland ecosystem had their own floral and faunal compositions which have been severely disturbed.

One of the important wetland was Chaqar located in the south of Matta Town which was protected as game reserve by the ruler of Swat and was visited by thousands of waterfowls every year till 1970. It was reclaimed into a cropland. Not only the reserve is lost, but the associated biodiversity, i.e., migratory birds and the plentiful fishes, have gone forever. The magnificent swamps of *Carex indica, Scabiosa* spp., and *Achorus calamus* have been permanently vanished away from the scene. Other such wetlands were the present rice paddies of Udigram/Balogram and Chakdara areas, which were mostly cultivated as monocrop for rice and remained as fallow marshes for the rest of the year.

2.13.1.5 Genocidal Prey

The destructive practices of dynamiting, electrification and poisoning of water, and the unchecked shooting of game birds have broken down the natural ecosystem. Swat River, which generally has high flow and natural fish reserves, has got somewhat protection from the unwise hunters and fishermen. They mostly kill the aquatic fauna of the tributaries during the low-flow season, through the destructive means of dynamiting, poisoning, and electrifying water, which is recurrently supplied by Swat River in the high-flow seasons. Unlike fishes, the innocent game birds got little natural protection and high exposure to the cruel shots of the hunters, that is why a very little percentage (5–10 %) may escape from shooting down here.

2.13.2 Indirect Impact

The indirect impact of man on Swat River and its tributaries includes depletion of recharge sources, siltation problem, agricultural seepage, and the depletion of biodiversity. These are summarized as below.

2.13.2.1 Depletion of Recharge Sources

It is a general observation that the mountains having forests have perennial springs and those lost forests have last the springwater. The forest watersheds generally conserve water through retarding the rain runoff and providing more absorption area to the rainwater. The losses of forest cover in the watersheds resulted in increased runoff and hence little water conservation.

2.13.2.2 Siltation Problem

The increased runoff on rainwater or snow melts causes erosion on the open slopes, which on the one hand causes soil erosion, i.e., decreased soil fertility, and on the other hand, the rock material covers the stream basin and impairs the breeding sites of migratory fishes.

2.13.2.3 Agricultural Seepage

The role of Swat River as a sink is generally not recognized, though most of the agricultural wastes are directly disposed off to the river. It is generally the high flow, rushing behavior, and expanded basin that rectify the effect. The leaching fertilizers and pesticides could also cause problem, but it is generally the high relief, heavy rainfall, and low input of farmer which cause practically no problem presently.

2.13.2.4 Depletion of Biodiversity

One of the most permanent features of the aquatic habitat all over the river and its tributaries is its biodiversity. Just from the alpine, the water passes across a variety of herbs, deciduous, and evergreen temperate forest, the low-lying alders, and willows associated with diverse animal fauna. Almost all of the biodiversity contribute in one way or the other to the health and continuity of the water body. One of the beautiful examples is alders growing on the river basin. It contributes a substantial amount of dissolved nutrients such as nitrates to the water. Their leaf contains four times as much as nutrients available in the leaves of other deciduous trees (Goldman 1961; Mills 1980). It also prevents overshading, maintains soil fertility, and controls erosion. Their root provides habitat and excessive oxygen supply for fish breeding. Their leaves enrich the water in available nutrients. Besides providing fuel, timber, and packing material, it also allows access for recreation and stream management. Recently, the modern trend of monoclonal adoption has introduced popular habitats of wallows and alders, thereby not only changing the natural balance of the traditional species but also depleting the role of alder in the ecosystem. Hundreds and even thousands of other examples regarding the positive role of the local biodiversity can be quoted in this regard. It is hurting to know that the natural floral biodiversity is diminishing at the expense of the fast-growing monoclones and the faunal diversity is exposed to excessive use.

2.14 Unplanned Population Growth

Unplanned population growth generally leads to natural degradation. Like most of the areas in the country, the population of Swat increased very fast. It increased both horizontally and vertically, resulting in the enhancement of family number and family size, respectively. The unplanned growth associated with the natural demand for more food, space for habitation, availability of potable water, agricultural and recreational lands, sanitation health, roads, capital, and cultural amenities created pressure on the whole of natural resources, especially on the health of water bodies. Swat River is generally considered as a resource for drinking, irrigation, hydropower, fish catch, watermills, transport, and game birds for prey. Its role as a sink for absorbing and converting all the refuse of animal and plants origin in to useful inorganic substances processed in to the precious biological products such as herbage or flesh is never recognized. It is clear from the pollution survey of Swat River (Ahmad 1999) that at some places (e.g., Mingora), the unplanned growth adds more refuse than the carrying capacity of the river, resulting in the potability of its water. The said survey concluded that there is a limited potability risk in the water of Swat River and the risk increase downstream, especially downstream Mingora, where it gets the municipality wastes as well from the city. Hence, the unplanned settlements all over the area, especially near the Swat River, need efficient sanitation, so that their waste may not hamper the natural absorbing capacity of the river.

The impact of unplanned population growth on natural resources is evident in the eutrophicated Jambel Khawar, to which all the solid and liquid wastes of the nearby settlements are directly deposed off. A few decades back, neither the population was too much and highly unplanned nor the use of this stream as a resource both for drinking water and fish catch. Presently, neither its water is useable nor fish population can withstand the cruel change. Rather the resource has been changed into a permanent problem.

Besides its direct effects, the unplanned population results in deforestation for both subsistence and terrace formation. To suffice their dietary need, more animals need to be reared which generally result in overgrazing. The increased unplanned population gave rise to deforestation, overgrazing, and more terrace cultivation, resulting in increased runoff of rainwater, accelerated soil erosion, decreased soil fertility, and siltation problems in the valley. All these practices have depleted the water conservation capacity of the mountain ranges and have therefore resulted in reduced recharge and percolation potentials of the area.

2.15 Conclusions and Recommendations

- Historical reports supported by the present demographic data reveal that the unplanned population growth in Swat valley is crossing the limits of sustainable carrying capacity of its natural resources. Which is leading to the deterioration of social as well as natural environment: population management through the processes of effective health education, realistic settlement zoning/planning, redetermining the royalty rights, and immigration control in the catchment?
- The resource base of Swat River is shrinking day by day, through the depleting wetlands, misuse of biodiversity, and denudation of its recharge base. The situation can only be tackled through creating national parks in the watersheds, game, and fish reserves across the river.
- The increased refuse disposal to Swat River is a serious threat, which impedes the carrying capacity the Swat River and the socioeconomic condition of the people of Swat as well. It must be controlled through treating the wastes locally.
- An effective liaison is a real need to integrate the line departments and environment-conscious NGOs and the social activists for evolving effective strategies to protect and conserve nature in the valley.

- Countrymen need to be educated for quantifying their shares towards the deteriorating nature and must be organized for playing their role in the conservation of nature locally.
- Unplanned population growth particularly in or around the watercourses and intact forests needs immediate control and replacement.
- Degraded watersheds not only create problems of siltation and changes of watercourses but also hamper the availability, flow, and quality of water. Its protection and proper management with the endemic flora is unavoidable.
- Extension of agroforestry, especially in the terraced watersheds, will not only protect the biodiversity but also ensure the conservation of water and soil resources. Besides all others, it can also improve per unit farm production and can raise the socioeconomic condition of farmers as well.
- Effluents from Mingora city in the form of Jambil Khwar are presently the largest and most serious threat to the health of Swat River and its dependents downstream Mingora; it needs proper treatment (Table 2.4).

Appendix I: Some Economically Important Plant Species of Swat

Family	Botanical name	Local name	Description of Plant use[a]
Acanthaceae	*Adhartoda vasica* Nees.	Baikar	6, 10
Adiantaceae	*Adiantum cappillus -veneris* L.	Bar Sumbal	6, 13, 27
	A. incisum Forsk	Bar Sumbal	6, 13, 27
	A.venustum D.Don.	Babozae	6, 13, 27
Alismatceae	*Sagittaria sagittifolia* L.	Taqae	4, 32
Alliaceae	*Allium ascalonium* L.	Piazakae	6, 17
	Allium jacquemontii Kunth.	Zangah Paiz	28, 17, 30
Amaranthaceae	*Achyranthus aspera* L.	Buch Kanda	6, 4
	Amaranthus caudatus L.	Chalwaye	2, 4, 5
	A. viridis L.	Ganrkar	2, 4, 5
Amaryllidaceae	*Narcissus tazetta* L.	Gwale Nargas	18, 6
Anacardiaceae	*Cotinus coggyria* Scop.	Miswakae	13, 6, 10, 24
	Rhus simialata Murr.	Thitrae	6, 17, 4
	Rhus punjabinsis Stewart	Rakhkal	7, 6

Family	Botanical name	Local name	Description of Plant use[a]
Araceae	*Acorus calamus* L.	Skha Waja	6, 13, 32
	Arisaema jacquemontii Blume	Wara Marjarai	7, 6
	A.utile Hook.f.ex.Schott	Tora Marjarai	7, 6
	A.tortuosum Roxb.	Ghata Marjari	7, 6
	Sauromatum venesum (Ait) Scoth.	Mar Jarai	7, 6
Araliaceae	*Aralia cachemirica* Decene	The Dadono Binakai	37, 39, 40, 10
	Hedra hilex L.	Palool/Pairwata	4, 6, 10
Ascelpediaceae	*Periploca aphylla*	Barara	6, 45
Balsaminaceae	*Impatiens bicolor* Royle	Writh Athrang	19, 4, 16
	Impatiens brachycentra Kar.& Ker.	Spin Athrang	4, 6, 19
	Impatiens edgeworthii Hook	Ziar Athrang	19, 4, 6
	Impatiens flemingii Hook. f	Gulabi Athrang	19, 4, 1, 6
Berberidaceae	*Brberis lycium* Royle	Kwarai	6, 29, 10, 1
Betulaceae	*Betula jacquemontii* Dene	Braj	12, 30, 22, 37
	Alnus nitida (Spach.) E.	Girae	32, 16, 10, 15
Brassicaceae	*Capsella bursa-pastoris* (L.) Medik	Bambesa	6, 4
	Sisymbrium irio L.	Awrae	6, 4
	Nasturtium officinale R.Br.	Talmira	6, 30
	Nasturtium microphyllum Boen.ex.Reichb.	Talmira	2, 6, 4
Buxaceae	*Buxus Pappilosa* C.K.Schneid.	Shamshad	6, 10, 37
	Sarcococca saligna	Ladanr	6, 10
Cactaceae	*Opuntia dillenii* Haw.	Zookam	13, 36
Caeseplinaceae	*Caesalpinia decapitala* (Roth) Alston.	Jara	36
Cannabidaceae	*Cannabis sativa* L.	Bhang	6, 10
Caprifoliaceae	*Viburnum cotinfalium* Wall ex.D.Don	Ghamzewa	1, 6, 29, 36, 10
	Viburnum grandiflorum	Ghamzewa	1, 6, 29, 36, 10
Caryophyllaceae	*Silene conoidea* L.	Bashka Mashora	4, 5
	Silene vulgaris (Moench.) Garcke	Mataranga	4, 5
	Stillaria media (L.) Chyr.	Tighstargai	2, 4, 5

Family	Botanical name	Local name	Description of Plant use[a]
Chenopodiaceae	*Chenopodium album* L.	Sarmae	2, 6, 4
	Chenopodium botrys L.	Skha Khawra	6
	Chenopodium ambrosoidis L.	Benakae	6
Colchicaceae	*Colchicum luteum* Baker	Suranjan/ Ziargulae	6
Combritaceae	*Thaltictrum falconeri* Leconeri	Mamera	6
Compositae	*Achillea millefolium* L.	Karkara	6
	Artimisia maritima L.	Tarkha	6, 7, 8
	A. scoparia L.	Jaokae	6, 34, 10
	Calendula arvensis L.	Ziar Gulae	6
	Carthamus oxycantha L.	Kareza	6
	Cichorium intybus L.	Han	2, 6
	Cincus benidictus L.	Sharai	4, 5, 2
	Helianthus tuberosus L.	Aloopach	2, 18, 38
	Onopordeum acanthium L.	Wrejakai	6, 4
	Sonchus asper L.	Shawda pai	4
	Taraxicum officinale Weber.	Ziar Gwalae	6
	Xanthium strumarium L.	Gishkae	10, 6
Convolvulaceae	*Cuscuta reflexca* Roxb.	Neladarai	8
Crasulaceae	*Sedum ewersii* Ledeb.	Tha Gat Warkharae	6
Cucurbitaceae	*Melothria madraspatana* (L.) Long.	Kakora	6
	Citrulus colocynthis L.	Karkunday	4, 6
Cupressaceae	*Juniperons communis* L.	Gugar	10
Cyperaceae	*Carex indica* L.	Thaspa Boutai	32, 23,
Dennstaedtiaceae	*Pteridium equilinum* (L.) Kuhn.	Kwanjae	2, 6, 27
Dioscoraceae	*Dioscora deltoides* Wall.	Kanis	31, 6, 27
Ebenaecae	*Diospyrus lotus* L.	Amlok	1, 30, 6, 12, 10, 16
Elaegnaceae	*Elaegnus umbellata* Thunb.	Ghanamranga	1, 10, 36, 29, 6
Equisetaceae	*Equisetum arvense* L.	Bandakae	6
Ericaeae	*Rhododindron hypenantheum* Balf.	Gulnamer	6
Euphorbiaceae	*Euphorbia hirta* L.	Krachae	7
	Euphorbia prostata	Warmaga	6
	Ricinus communis L.	Aseela Harlanda	6, 10

Family	Botanical name	Local name	Description of Plant use[a]
Fagaceae	*Q.incana roxb.*	Banj	10, 4, 1, 12, 29, 43, 38
	Q.semicarpifalia	Kaanar/Mer	12, 10, 38
	Q.Ilex. L.	Serai	10, 43, 38, 29
	Q.dialatta Lindl.	Jaran	10, 4, 38, 29, 43
Guttiferae	*Hypericum perforatum* L.	Shin Chai	3, 6
Sapotaceae	*Reptonia buxifolia* A.DC.	Gwargwara	1, 10, 29
Hamamelidaceae	*Parrotiopsis jacquemontiana* (Done) Rehder.	Beranj	25, 24, 10, 38
Hippocastinaceae	*Aesculus indica* (Wall ex Cambl.) H.K.f	Jawaz	6, 4, 8, 10, 12, 16, 30
Iridaceae	*Gynandrisis sisyrinchium* (L) Parl.	Gandechar	7, 6
	Iris versicolor L.	Oudi Thurai	18, 6
Juglandaceae	*Juglens regia* L.	Ghouz	33, 1, 4, 6, 17, 18, 19, 12, 35, 41, 10
Labiatae	*Stychus parviflora* Benth	Sper bootae	10, 6
	Ajuga bracteosa Wall. ex. Benth.	Khawaga Bouti	6, 31
	A. parviflora Beth.	Tarkha Bouti	6, 31
	Mentha piperita L.	Yakha Podina	17, 6
	Mentha spicata L.	Podina	17, 6, 3
	Mentha sylvestris L.	Yenalae	6, 17, 3
	Micromeria biflora (Ham.) Bth.	Narae Shamakae	6, 39
	Origanum vulgare L.	Shamakae	39, 6
	Salvia moorcruptiana Roxb	Kharghwag	6
	Teucrium incanum Aitch & Hombsl.	Kwandi boutae	6
	Ocimum basilicum. L.	Kashmakae	18, 6, 17, 21
Laliaceae	*Polygonatum verticillatum* All.	Baramola	6
	Asparagus adscendens Roxb.	Thindarae	35, 6
	Astragalus anisacanthus Boiss.	Mamol	35, 6
	A.phyrrhotrichus Boiss.and Hohen.	Mamol	35, 6
	A.psilocentros Fisch		35, 6
	Gaega pseudoreticulata Wed	Qaimath Gulae	7
	Tulipa stillata H.K.	Ghantol	6, 4
Malvaceae	*Malva neglecta* Wallr.	Panerak	2, 4, 5
	Malva officinalis	Sonchal	2, 4, 5
	Malva sylvertris	Panerak	6, 4, 2, 5

Family	Botanical name	Local name	Description of Plant use[a]
Meliaceae	*Cedrela serrata* Royle	Skhawounae	31, 12, 7
	Melia azedrach L.	Shandai	16, 4, 6, 30, 10
Moraceae	*Ficus palmata*	Inzar	1, 4, 10, 6
	Morus alba L.	Baidana	1, 4, 12, 30, 10, 15, 16
	Morus nigra L.	Thooth	1, 4, 12, 30, 10, 15
Myrsinaceae	*Myrsine africana* L.	Marorang	6, 10, 38, 27
Nyctaginaceae	*Mirabilis jalapa* L.	Gule Bada	6, 18
Oleaceae	*Fraxinus excerlsior* L.	Shoom	4, 36, 10, 29
	Jasminum humile.	Rambel Chambel	21, 18, 29, 10
	Jasminum officinale	Ziar Rambel Chambel	21, 18, 29, 10
	Olea ferruginea Royle	Khona	4, 1, 38, 10, 16
Paeoniaceae	*Paeonia emodi* Wall.	Ward, Mamekh	6,
Papaveraceae	*Fumaria indica* (Hausskn) Pugsly.	Papra	6, 4, 5
	Aregemone maxicana L.	Raidae	6, 18
	Corydalis stewarttii Fedde	Mamera	6
Papilionaceae	*Dalbergia sisso* Roxb.	Shawa	30, 37, 38, 10, 12, 41
	Indigofera gerardiana Wall.	Ghwareja	24, 37, 24, 45, 46, 44
	Indigofera weightii	Ghwareja	4
	Lathyrus aphaca L.	Kur Kamanai	4, 2, 5
	Lathyrus cicra L.	Wara Chilo	4, 2, 1, 5
	Lathyrus sativus L.	Ghata Chilo	4, 5, 2
	Lathyrus pratensis L.	Ziara Chilo	4, 5
	Medicago denticulata	Shpeshtarae	4, 14, 6, 5
	Robinia pseudoaeacia L.	Kikar	36, 10, 4, 29
	Vicia faba L.	Marghai Khpa	4, 5, 14, 3
	Vicia hirsuta (L.) S.F.Gray	Mardikakh	4, 5, 14, 3
Phytolacceae	*Phytolacca labthenia* (Mog.) Walt.	Garrar	2, 6, 20, 19
Pinaceae	*Abies pindrow* Royle	Achar	38, 37, 26, 10, 29, 30
	Pinus gerardiana Wall. ex Lamb.	Nakhtar	26, 10, 38, 30, 18
	Pinus roxberghii Sargent	Nakhtar	28, 1, 10, 26, 30, 11, 13, 18
	Pinus wallichiana A.B. Jackson	Sraf	26, 30, 10, 11, 13, 18
Pistaciaceae	*Pistacia integerrima* Stewart	Shnai	6, 4, 10, 29
Plantaginaceae	*Plantigo lanceolata* L.	Jabai	4, 6
	Plantigo major L.	Ghata Jabai	4, 6
	Plantigo ovata Forsk.	Wara Jabai	4, 6
Platanaceae	*Platanus orientalis* L.	Chinar	16, 30, 12, 18

Family	Botanical name	Local name	Description of Plant use[a]
Poaceae	*Aristida adscensionis* Nees	Mashkar	4, 5, 34
	*A.cynantha ex.*Stued.	Mashaanrae	4, 5, 34
	Chrysopogon aucheri	Spin Wakha	4, 5, 24
	Chrysopogon gryllus	Spin Wakha	4, 5, 24
	Chrysopogon montanus Trin.	Spin Wakha	4, 5, 24
	Cenchrus pennisetiformis (Hoechest) Stued.	Pisho Lamae	4, 5
	Cenchrus cilliaris	Pisho Lamae	4, 5
	Cynodon dactylon L.	Kabal	4, 5, 18
	Desmostachya bipinnata (L.) Stapf.	Drab	4, 5
	Phragmites communis Trin	Sharghashae	37
	Sacchrum monja Roxb.	Nal	36, 37, 13
	Sacchrum spontaneum L.	Sharghashe	37, 13
	Sorghum helepense (L.)Pers.	Dadam	4, 5
Podophyllaceae	*Podophyllum emodi* Wall.	Gangora	6
Polygonaceae	*Rumex acetosa* L.	Tarokae	2, 6
	Polygonum aviculare	Palpolak	6, 31
	Polygonum viviparum L.	Anjabar	6, 4
	Rheum webbianum Royle	Ghoutyal	6
	Rumex dentatus L.	Shalkhae	2, 6
	Rumex alpinus L.	Thaghm Shalkhae	2, 6
Portulaceae	*Portulaca oleracea* L.	Warkharai	2, 6
Punicaceae	*Punica granatum*	Anangorae	1, 29, 10, 6, 17
Ranaculaceae	*Aconitum chasmanthum* Stapf. ex Holmes	The Ghra Zahar	7, 6
	Aconitum hetrophyllum Wall.	Zahar mora	7, 6
	A. violaceum Jacq. ex. Stapf.	-do-	7, 6, 13
	Anemone obetusiloba D.Don.	The Spinsar Bouti	4, 13
	A. rupicola Comb.	The Spinsar Bouti	4, 13
	Aquilegia pubiflora Wall.	Woudi Gwalae	6
	Caltha alba Jacq.ex.Camb.	Makhanr Path	2, 6, 4
	Clematis orientalis L.	Zelai	6
	Coptis teeta Wall.	Mamera	6
	Dilphinium roylei Munz.	Oudi Gulae	18
	Dilphinium pyramidale Royle	Oudi Gulae	18
	Galium asperifoleum Wall.	Tha Kargh Makookha	4, 1
	Rananculus muricatus L.	Quazi Ban	4, 6
Rhamnaceae	*Ziziphus jujuba* Mill.	Markhanai	33, 1, 6, 10, 36, 37, 4

Family	Botanical name	Local name	Description of Plant use[a]
Rosaceae	*Cotoneaster affinis* (Lindl.) Schn.	Kharawa	6, 10, 37
	Cotoneaster microphylla Wall.	Kharawa	10, 6, 1, 25
	Cotoneaster numularia Fisah & Mey.	Mamanra	10, 6, 25
	Crataegus oxycantha HK.f.	Tampasa	6, 29, 10, 1
	Fragaria indica Andrews	Tha Zmake Thooth	6, 1
	Fragaria nubicola Lindl.	Tha Zmake Thooth	1, 6
	Prunus cornuta (Wall). Steud.	Changa	4, 1, 29, 33, 29, 10
	Pyrus pashia	Tanga	42
	Rosa brunonii Lindl.	Khwarch	36, 44
	Rubus fruticosus L.	Karwara	36, 29, 1, 6
	Rubus idaeus L.	Baganai	36, 29, 1, 6
	Rubus sanctus	Goraja	29, 1, 6
	Rubus ellipticus	Ziara Karwara	29, 1, 6
	Sorbaria tomentosa (Lindle) Rehder.	Jijrai	4, 10, 29
Rutaceae	*Skimmia laurefola* (DC.) Sieb &Z ucc. ex.Walp.	Nazar Panra	40, 6
	Zanthoxylum aromatum DC.	Dambara	25, 36, 29, 17, 6
Salicaceae	*Populus alba* L.	Watani Sperdar	8, 10, 38
	Populus ciliata Wall.	Parra	10, 38, 16, 13
	Populus euphratica Oliv.	Sperdar	14, 30, 37, 13, 15, 38, 37
	Populus nigra L.	Sperdar	30, 37, 10, 15
	Salix babylonica L.	Aseela Wala	13, 16, 4, 10, 32, 12
	Salix tetrasperma Roxb	Wala	13, 16, 4, 10, 32, 12
	Salix flabellaris Anders	Tha Ghra Wala	4, 10, 13
Sambucaceae	*Sambucus wightiana* Wall. ex Wight & Arn.	Benakai	4, 6
Saxifragaceae	*Berginia ciliata* (Haw.) Scernb.	Gat Panra	6, 18
	Berginia stracheyi (Haw & Thoms) Engl.	Gat Panra	6
Scrophulariaceae	*Varbascum thapsus* L.	Khar Dag	6
	Veronica ciburia (L.) Less	Shamakae	6
Simarubaceae	*Ailanthus altissima* (Mill.) Swingle	Aseela Shandai	10, 4, 13, 15, 30, 29

Family	Botanical name	Local name	Description of Plant use[a]
Solanacae	*Atropa acuminata* Royle ex.Lindl.	Garar/Bargak	7, 6
	Solanum nigrum L.	Kamachoo	2, 6
	Solanum xanthocarpum Schard & Wendl.	Maraghoonae	6
	Withania sommifera Dunal	Kotilal	7, 6
	Datura metel L.	Harhanda	6, 7
	Datura stramonium L.	Harhanda	6, 7
Taxaceae	*Taxas baccata* L.	Banrya	38, 4, 10, 12, 9
Thymeleaceae	*Daphne mucronata* Royle	Leghonae	6, 10
Ulmaceae	*Celtis australis* L.	Thagha	6, 12, 30, 16
	Celtis leavigata Willd.		1, 37
	Ulmus wallichii With.	Kahae	4, 10, 38, 16
Umballiferae	*Eryngium biebersteinianum* Nevski	Tha ManzariMangwal	6, 4
	Anethum sowa Roxb.ex.Flem.	Sowah	6
	Prangos pobularia Lindl.	Kamasle Zankai	6
	Trachyspermum ammi	Sperkai	6
	Carum bulbocatanum	Tore Zankai	6, 30, 17
	Carum carvi L.	Sperkai	6
	Bumium persicum (Prios) Fedtsch.	Zankai	17, 6
Utricaceae	*Utrica dioca* L.	Lawane Sezoonkae	2, 6
	Utrica pilulefora L.	Sezoonkae	2, 6
Valerianaceae	*Valeriana jatamansi* Jones	Shingatai	6
Verbenaceae	*Vitex negundo* L.	Marwandai	8, 6
Violaceae	*Viola serpens* Wall.	Banafsha	6, 2
	Viola kashmiriana W.Bkr.	Banafsha	6, 2
Vitaceae	*Vitis vinifera* L.	Kwar	1, 4, 6
Zygophyllaceae	*Tribulus terristris* L.	Markoondai	6

[a] Key to plant use description

1. Wild fruit	13. Soil binder	25. Sticks/handles	37. Utensils
2. Potherb	14. Soil fertilizer	26. Timber	38. Construction
3. Beverage	15. Windbreak	27. Cushion plant	39. Bee attractants
4. Fodder	16. Shade tree	28. Resin	40. Smoking medicine
5. Hay fodder	17. Spice/flavoring agent	29. Fence	41. Wood carving

6. Medicine	18. Ornamental	30. Furniture	42. Rootstock
7. Poison	19. Dye	31. Fish poison	43. Charcoal
8. Green pesticide	20. Ink	32. Soil reclamation	44. Fishing checks
9. Graveyard things	21. Incense/perfume	33. Dry fruits	45. Snuff ash
10. Fuelwood	22. Paper	34. Brooms	46. Granary/ basketry
11. Torchwood	23. Beads	35. Miswak	
12. Agricultural tools	24. Packing/roping	36. Hedge plant	

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Chapter 3
The High-Mountain Flora and Vegetation of the Western and Central Taurus Mts. (Turkey) in the Times of Climate Change

Gerald Parolly

3.1 Introduction

3.1.1 The Western and Central Taurus Mts., a Highly Diverse High-Mountain Range

The Taurus Mts. (Turkish: Toroslar) in Turkey represent the westernmost SW Asian-type of a high mountain range with a semiarid vegetation zonation. High-mountains are generally defined as mountain systems reaching altitudes above the natural forest line caused by low temperatures. In high-mountain environments, where trees fail to grow, the average mean temperatures normally range below 6–8 °C during the vegetation period (Körner 2003). In addition, high-mountains are marked by an ensemble of periglacial relief features due to past or extant glaciations, as well as active cryoturbation processes (Troll 1966). Such an "alpine life zone" (Körner 2003) occurs globally in all climate zones. In Europe and adjacent regions, subarctic (N Ural), boreal (Scandinavian Mts. p. p.) and temperate-nemoral (e.g., Alps, Carpathians, and Pyrenees) high mountains can be distinguished from Mediterranean high-mountains (Pauli et al. 2011; Richter 2001). Distinct by climate and vegetation, Mediterranean-type high-mountains form isolated "islands of low temperatures," rising over much warmer and drier surroundings. Typical examples coming from the southern edge of Europe include the Spanish Sierra Nevada, Mount Etna, and the mountains of Crete. As a subtype, the High Atlas in N Africa and the Taurus Mts., the Lebanon Mts., and the Alborz Mts. in SW Asia might also be considered here.

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The remarkable bioclimatic, geomorphological, and pedological diversity of the Toroslar supports a great many of different high-mountain vegetation types (see for a synopsis, Parolly 2004) and an extremely rich flora, which boasts high rates of endemism. The most diverse centers of endemism in Turkey are located here (Davis 1971; Ekim 2007; Ekim and Güner 1986; Ekim et al. 2000; Eren et al. 2004; Kürschner 1984; Özhatay et al. 2003; Parolly 2004; Parolly et al. 2010).

Since there is no overall floristic treatment covering the whole Taurus Mts. except for the "Flora of Turkey" (Davis 1965–1985; Davis et al. 1988; Güner et al. 2000), we have to refer to various other sources to substantiate the just given statements. Already a first look on maps, compiling the numbers of endemic taxa and rate of endemism per "Flora of Turkey" grid (Davis 1965) clearly shows that all seven grids (out of 30 in total) with more than 400 endemic species are connected with the extension of the Toroslar (including the Anatolian Diagonal; Özhatay et al. 2003). Similar impressive figures are revealed by focusing on the number of endemic plant taxa of those Turkish vilayets (provinces) with large portions of their territories being part of the Taurus Mts., such as Adana (470 taxa), Antalya (840), Burdur (300), İsparta (446), Kahramanmaraş (502), Muğla (479), and Niğde (507; see Torlak et al. 2010).

In general, the rate of endemism per "Flora of Turkey" grid is well above 20 % within the Taurus Mts. (Özhatay et al. 2003). In some of its massifs, total endemism rates of up to 30 % have been recorded (Eren et al. 2004). As a rule, the highest number of endemic species of the Taurus Mts. certainly concentrates in the lower elevations (montane belt complex s. l.), along with many different habitat types offered in the various forest ecosystems, gorges, and valley bottoms with xeric and hygric sites, cliffs, and scree, and a diverse geology. However, due to the normally very species-rich community inventories in these elevations, the percentage of endemism is lower than higher up, where endemic species (narrow endemics, Taurus endemics, and Anatolian-wide endemics) increasingly dominate the vegetation of scree slopes, cliffs, snow-patches, grasslands, and open dwarf-shrub and thorn-cushion communities (Hein et al. 1998; Kürschner 1982; Kürschner et al. 1998; Parolly 1995, 1998, 2004). Typical communities of high-mountain vegetation display percentages of endemic species ranging between ca. 20 and 60 %, often with rates of endemism rising with altitude, making the highest elevations of the area outstandingly important in terms of conserving the high-mountain diversity.

3.1.2 The High-Mountain Flora and Vegetation of the Western and Central Taurus in Times of the Global Warming

We live in the "anthropocene," and global warming appears to be a matter of fact (e.g., Essl and Rabitsch 2013). High-mountain environments represent one of the most sensitive ecosystem complexes to global warming. Provided that current predictions of global warming scenarios (temperature increases of 1.1–6.4 K till 2099, IPCC 2007) are correct, significant changes in plant diversity in mountain ecosystems (Erschbamer et al. 2010; Gottfried et al. 1994; Grabherr et al. 1994, 2001; Guisan and Theurillat 2001; Körner 2003) should be expected. There is already much global evidence of an ongoing upward migration of species, changes in species composition and vitality of alpine plants, and an upward shift of whole vegetation belts (e.g., Grabherr et al. 1994; Walther et al. 2005). This reaction of plant life to recent climate warming is particularly well documented from nemoral and Mediterranean high-mountains (Erschbamer et al. 2009; Holzinger et al. 2008; Pauli et al. 2007, 2011; Vittoz et al. 2008; Walther et al. 2005).

Most of these data have been recorded within the GLORIA monitoring network (GLORIA-Europe = Global Observation Research Initiative in Alpine Environments and GLORIA-worldwide) in high-mountain regions by means of permanent plots on summits from the treeline ecotone to the subnival/nival zone (e.g., Grabherr et al. 2010; Pauli et al. 2004, 2007, 2009). No such data are available for the Turkish mountains and the Toroslar in particular, although the area is among the GLORIA target regions with "interest expressed" status by the author as part of the GLORIA network (www.gloria.ac.at).

3.1.3 Goals of the Present Contribution

Nevertheless, it appears possible to estimate some potential effects of the ongoing climate warming on the high-mountain vegetation of the Western and Central Taurus, its zonation, and its often endemic, cryophilic, and hygrophilic flora by evaluating vegetation studies, which reveal the vertical distribution patterns and site conditions of the taxa.

The threat analysis, below, is based on the following general assumptions and expected scenarios: A changing temperature regime through ongoing warming will expand the distribution ranges of taxa and vegetation belts upward. Therefore, cryophilic species (species adapted to cool places) colonizing the highest life zone of a particular mountain range are more threatened due to the limited possibility to continuously expand their ranges into higher terrains. Cryophilic high-mountain endemics are considered more vulnerable than widespread species; hence the focus on endemics and evaluation of community-based chorotype spectra.

In contrast to nemoral mountain systems, in Mediterranean-type and in subtropical-summer dry high-mountain systems in general, the hygric factor can gain more importance than the thermic factor (Richter 2001; Pauli et al. 2011). Hypothetically, climate warming is coupled with a shift of factors influencing the precipitation regime, causing extended xeric conditions in high elevations and reduced amounts of precipitation in the Taurus Mts. Together with increasing temperatures, this would result in an earlier and quicker snowmelt, shorter and lower snow-cover, gradual meltdown of the few remaining block glaciers, less water supply for temporal and permanent water runnels and courses, etc. Such effects would also be clearly due beyond the alpine belt, affecting all kinds of meso- to hygrophytic vegetation in oreal and subalpine elevations.

This may not only lead to potential habitat losses or at least a reduced vitality for cryophilic plants of the highest elevations but also hold for all hygrophilic plants closer bound to damp or moist places in the high mountains. Both groups will include taxa, which in the following are termed "species possibly affected by climate change" (SPAC).

This study has the following major goals: Besides providing a short review on the high-mountain vegetation of the Western and Central Taurus and its position within the Tauric System (Parolly 2004), it attempts identifying

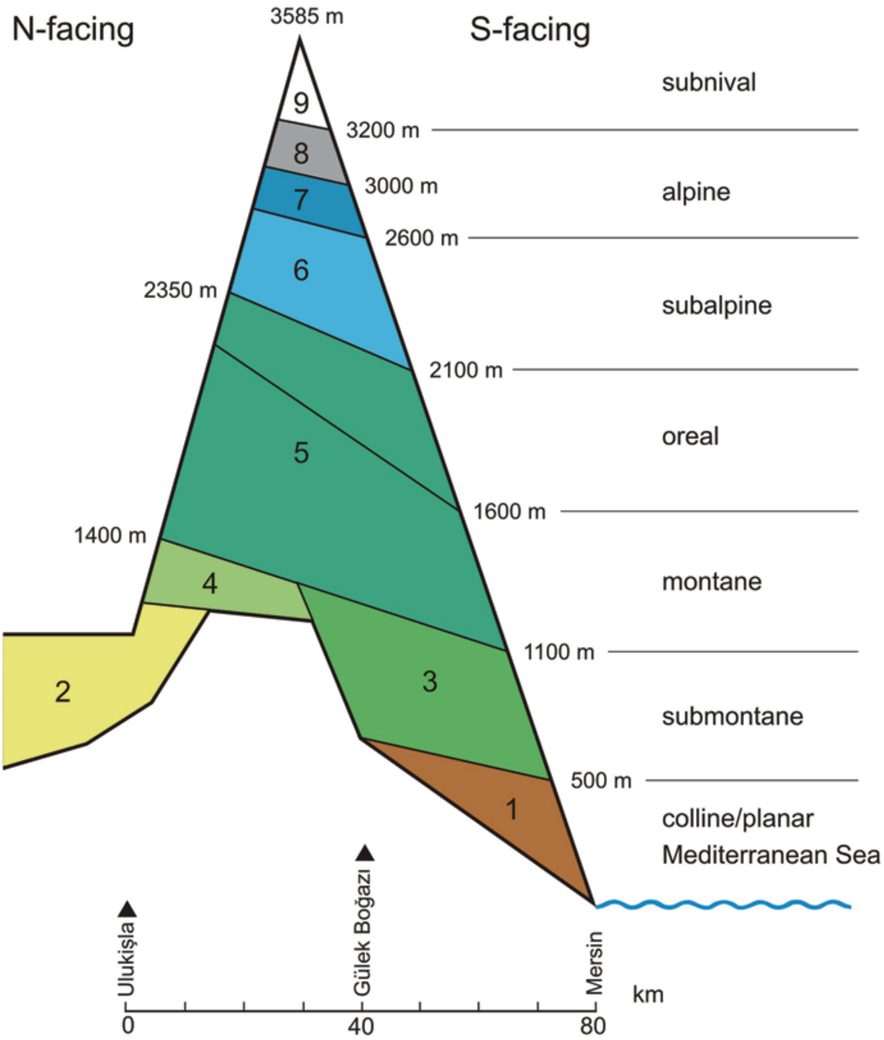

Fig. 3.1 The Tauric Zonation [**1** Mediterranean sclerophyllous forest and scrub; **2** open, xerophytic dwarf-shrub stands (*Artemisia steppe*); **3** evergreen needle-leaved forest sensitive to cold (*Pinus brutia forest*); **4** open cold-deciduous forests without evergreen woody species (mostly degraded to *Quercus pubescens* shrubland); **5** evergreen needle-leaved forest resistant to cold (*Pinus nigra* var. *caramanica* forest); **6** open thorn-cushion formation; **7** alpine grassland; **8** high mountain scree formation, rock and wind-swept communities; **9** subnival vegetation]

(i) The cryophytic and hygrophytic plant communities of the high altitudes (Sect. 3.4);
(ii) The vascular plant species possibly concerned by climate change (Sect. 3.5 and Appendix);
(iii) The vascular plant species exclusive to the highest life zone of the Western and Central Taurus (Appendix and Fig. 3.1).

Moreover, it tries to answer the following questions: Does a correlation between the altitudinal and geographical distribution patterns of the species exist? Which threats and implications for conservation biology may arise for cryophilic and hygrophilic narrow endemics?

3.2 Brief Description of the Study Area

Situation, Geology, and Delimitation of the Study Area. Turkey is bordered by two prominent mountain ranges belonging to two different tectonic units, the Pontids in the north and the Taurids in the south. As part of the Tertiary Alpine upfold, they link geologically, tectonically, and geomorphologically the mountain foldstocks of the European Dinarids–Hellenids with the Iranian Alborz and Zagros Mts. In the west, the Taurus Mts. rise steeply from the Aegean Sea (ca. 28°E) and extend over ca. 2000 km to the Iranian border in the east (ca. 44°E), where they merge into the Zagros Mts. The Taurus Mts. are on average 50–100 km broad. They border on the Mediterranean Sea, delimit Inner Anatolia in the south and in the east and meet the N Anatolian Pontids near Erzincan, forming along the transverse mountain range a famous floristic break, the so-called Anatolian Diagonal (Davis 1971; Ekim and Güner 1986).

Geologically, the Toroslar is largely composed of sedimentary rocks, deposited in the former Tethys Sea (Güldalı 1979). Today, owing to the rapid orogensis during the (late) Tertiary, mainly Mesozoic sediments form the impressive alpine, glacially ice-sculptured scenery of the Taurus. In the eastern part of the Central Taurus, in particular Cretaceous layers exceed 2000 m and are often uplifted to altitudes of 3500 m or more. The rock is predominantly a hard limestone, but locally with substantial outcrops of ultramafic rock especially in lower and mid-elevations. Mica schist (e.g., Baba Dağı) and orthogneiss (Boz Dağı) make up single massifs in the West. The Sultan Dağları are composed essentially of strongly tectonized Lower Paleozoic formations (Brunn et al. 1971). Where limestone and dolomites prevail, extensive territories are subjected to karstic processes (cf. Güldalı 1970, 1979), providing particular sites for plant life (e.g., dolines).

Being a part of the Tertiary Alpine upfold, the Taurus Mts. form an anticlinal system consisting of a series of folded arches frequently broken and much distorted. Today, an orographical and tectonical division into three parts, based on the same number of main continuous or broken arch systems, is generally accepted, although their borders are still under discussion. For a terminology and map of the phytogeographical subdivision of the Taurus range, see Parolly (2004) and Parolly et al. (2010). The parts are called Western Taurus (Turkish: Batı Toroslar), reaching from Honaz Dağı eastward to the Aksu Çay; Central Taurus (Orta Toroslar), a complex, in which the mountain range of the Aladağlar is clearly included, and Eastern Taurus (Güney Doğu Toroslar; for details see Kürschner 1982, 1984; Parolly 1995). The Batı Toroslar rarely reaches altitudes of more than 3000 m and culminates in the Kızlar sivrisi (3086 m, Beydağları, Fig. 3.2j) and Lycian Akdağ (3024 m,

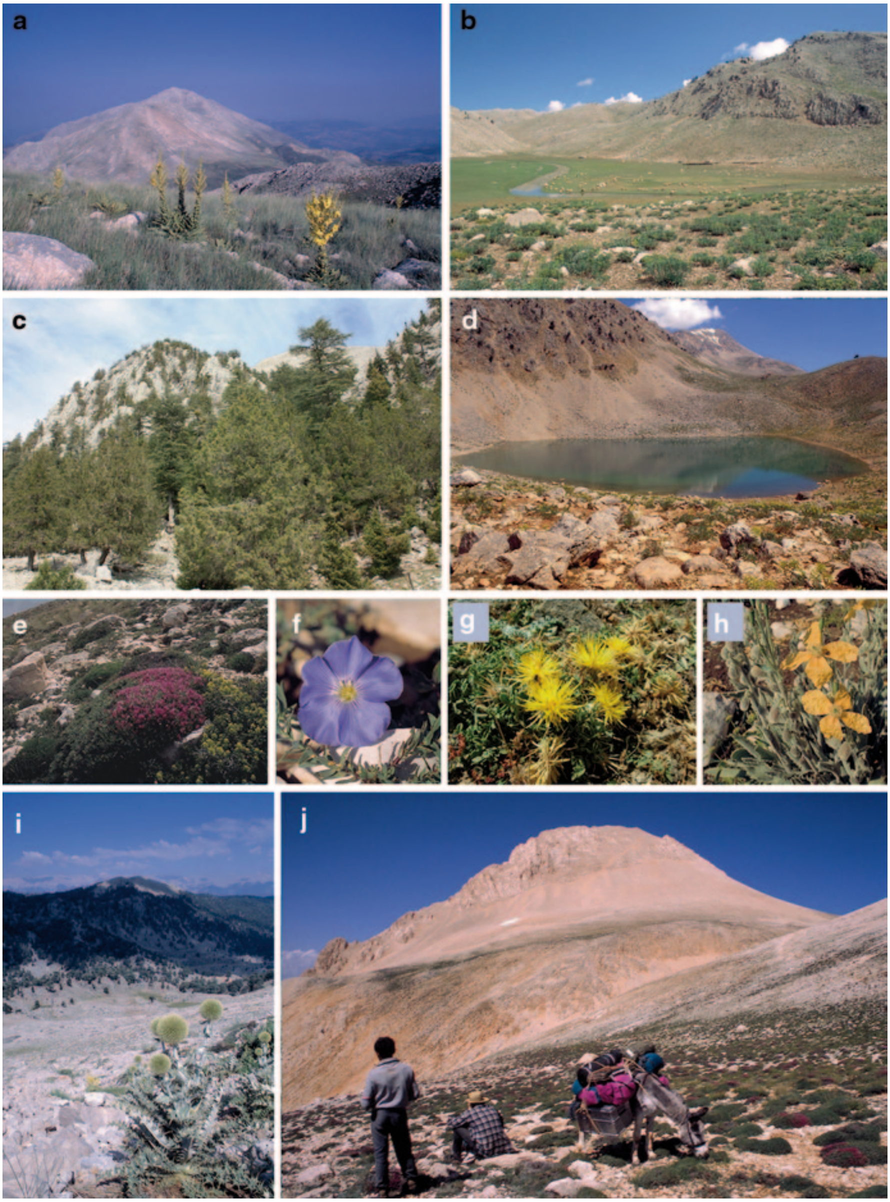

Fig. 3.2 Typical landscapes and habitats of the Western Taurus and western Central Taurus [**a.** *Elytrigia divaricata* limestone sward (Tanacetion praeteriti; Çalbali Dağı, 2200 m); **b.** degraded *Marrubium bourgaei* dwarf-shrub community (Tanacetion praeteriti; in the foreground) and Bolanthion frankenioidis turf and further hygrophytic vegetation in the doline along a creek (Yumru Dağı, 2000 m); **c.** mixed coniferous forest with *Abies cilicica* subsp. *isaurica, Cedrus libani, Pinus nigra* var. *caramanica* and *Juniperus* spp. (Gembos Yayla, Akseki, 1750 m); **d.** strongly browsed and degraded *Astragalus microcephalus* community (Tanacetion praeteriti) with abundant antipastorals such as *Euphorbia kotschyana* (Yeşil Göl, Lycian Akdağ, 1900-2100 m); **e.** thorn-cushion

Akdağlar). By contrast, the eastern part of the Central Taurus and the Eastern Taurus consist of extensive high-mountain ranges with arrays of peaks and summit regions exceeding 3200 m. The highest peaks (more than 3700 m) of the study area are situated in the Aladağlar, which mark its eastern border and the easternmost part of the Orta Toroslar.

The study area covers the high altitudes of the Western and Central Taurus range, approximately between the Honaz Dağı in the west and the Aladağlar in the east.

Climate Situated in a transitional zone between the S Anatolian Mediterranean climate and the Inner Anatolian steppe climate, the Taurus range is influenced by both climatic types. Especially in respect to precipitation, the main ridge of the Toroslar forms a strong barrier (Luvs-lee effect) between the NW- and SE-macroslopes of the mountain chains. While the S- and SE-slopes are characterized by a pronounced perhumid period (winter rains), few frosts, and warm summers (Mediterranean climate), most of the northern Taurus incline is influenced by the climate of the arid, summer-hot (summer depression) and winter-cold and snowy steppe region.

Based on data obtained according to the precipitation–temperature quotient of Emberger (1930, 1952), the high altitudes share in bioclimatic respects cold to very cold variants of the humid zone (Kürschner 1984). For more general accounts of the climate of Turkey, see Akman and Ketenoğlu (1986) and Garcia-Lopez (2001).

Especially during the vegetation period from May/June to October, a temperature regime predominates, which proved to oscillate about 40–50 K (Parolly 1995). In August, the air temperature in the alpine belt can drop down from +30°C in the early afternoon to well below 0 °C at night (max. −10 to −15 °C). The alpine and subnival landscape (Figs. 3.2j and 3.3a–c, h–i) bears the stamp of that resulting in an intensive thermic weathering, expressed in enormous talus slopes of scree and a rugged and steep mountain profile.

3.3 Methods

3.3.1 Data Sources

The evaluation of the communities and species potentially affected by global warming is based on published and unpublished vegetation studies following the conventions of the Braun-Blanquet approach (1964). A syntaxonomic synopsis of the high-

community dominated by *Onobrychis cornuta* (Tanacetion praeteriti; Bakırlı Dağı, 2.350 m); **f.** *Linum obtusatum*, an Anatolian endemic, in the Paronychion lycicae (Kızlar sivrisi, 2.700 m); **g.** *Centaurea pestalozzae*, a localised endemic of the Western Taurus, associated with the Paronychion lycicae (Tahtalı Dağı, 2.250 m); **h.** *Papaver pilosum* agg. (Tanacetion praeteriti, Lycian Akdağ, 2.300 m); **i.** *Echinops emiliae* in an initial limestone sward (Tanacetion praeteriti) within scree (Scrophularion depauperatae, Tahtalı Dağı, 2.150 m); **j.** thorn-cushion community dominated by *Onobrychis cornuta* (Tanacetion praeteriti–Paronychion lycicae transitions, 2.500 m, Kızlar sivrisi), in background the enormous alpine scree slopes (Ranunculo brevifolii-Thlaspietum sintenisii) of the summit range]

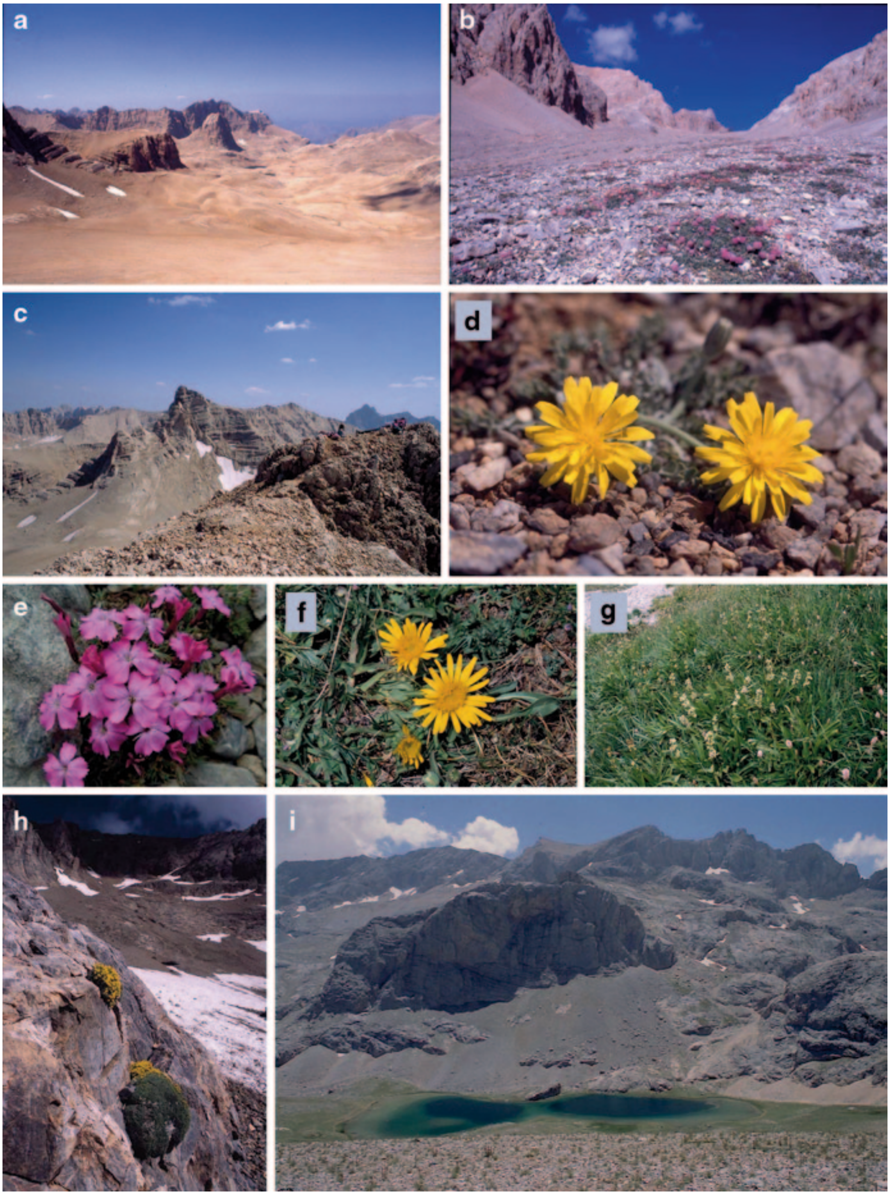

Fig. 3.3 Typical landscapes and habitats of the eastern Central Taurus (Bolkar and Aladağlar). **a** Subnival, glacially sculptured landscape of the Cilician Taurus supporting scree, wind-swept cushion and meltwater communities, and rock plants (Yedigöller, Aladağlar, 3300–3600 m), **b** high alpine-subnival wind-swept cushion community with *Ebenus laguriodes* var. *cilicica* (Yalak Deresı, Aladağlar, 3200 m), **c** cliffs and rock walls of the Engin-Tepe summit (3723 m) and view on Kızılkaya (3725 m; Aladağlar), **d** *Crepis willdenowii* (Yalak Deresı, Aladağlar, 3150 m), **e** *Dianthus brevicaulis* subsp. *brevicaulis,* endemic to the Cilician Taurus and the mountains further east, in a Drabo-Androsacetalia community (Tahtakaya, Bolkar Dağları, 3200 m), **f** *Inula acaulis* in a *Kobresia humilis* turf (Tahtakaya, Bolkar Dağları, 3100 m), **g** forb community with *Swertia*

mountain vegetation of Turkey is given by Parolly (2004). The same paper also refers to the major taxonomic and nomenclatural references used and the sources of more than 3550 phytosociological relevés available.

Of the following studied formations and syntaxa (Parolly 2004 and references cited therein), 2300 own relevés (partly unpublished) were available: Screes (Heldreichietea, Parolly 1995), rock vegetation (Silenetalia odontopetalae, Hein et al. 1998), thorn-cushion communities, dwarf-shrub lands and gappy subalpine limestone swards (Astragalo-Brometalia and, partly, Onobrychido armeni-Thymetalia leucostomi, Döring 2001; Tolimir 2001), alpine mat-forming communities and vegetation of wind-beaten mountain tops and exposed ridges (Drabo-Androsacetalia, Parolly, unpublished data), snowbeds and meltwater communities (Trifolio-Polygonetalia, Kürschner et al. 1998), and azonal hydro- and hygrophytic units, such as alpine turfs and low-sedge fens (Scheuchzerio-Caricetea fuscae, Hein et al. 1995; Parolly, unpublished data; Raab-Straube 1994).

The analysis concentrates on the asylvatic high-mountain vegetation of the Central and Western Taurus.

3.3.2 Vertical Ranges of Vegetation Units and Species

The high-alpine and subnival vegetation life zones show a highly scattered distribution over the Taurus Mts. West of the Cilician Taurus, the subnival zone is completely lacking, because only a few isolated peaks and massifs reach elevations of 2700 m and more (Lycian Taurus: Akdağlar: Lycian [= Gömbe] Akdağ, Yumru Dağı and Beydağları: Kızlar sivrisi; Pisidian Taurus: Dedegöl Dağları, Barladağı; Isaurian Taurus: Geyik Dağları with Büyük Geyik Dağı, and Akdağ). However, due to more Mediterranean conditions and the mass-elevation effect, the high-mountain vegetation zones are ca. 200 m lower in the west than in the east. In general, a phytosociological structuring of the major vegetation units into an oreal–alpine and an alpine–subnival group (alliance) is restricted to the high ranges of the Bolkar Dağları and Aladağlar.

Many summits, especially in the west (e.g., Honaz Dağı, 2571 m; Bakırlı Dağı, 2547 m; Bozburun Dağı, 2504 m; Şeytan Dağları, 2403 m; Küpe Dağları, 2551 m; Özyurt Dağı, 2481 m; and Oyuklu Dağı, 2440 m), extend almost to the alpine zone in its proper meaning. Field observations and vegetation surveys indicate the existence of a very narrow, though physiognomically and floristically particular vegetation belt along the highest ridges and summit plateaux clearly distinct from the "typical" subalpine units (e.g., Eren et al. 2004). This vegetation and zone is named here "pseudo-alpine" and certainly among the first to be affected by any climatic change. The

longifolia (Kayaçık Boğazı, Aladağlar, 2650 m), **h** Cliff with a stand, the subalpine Drabetum acaulis typicum (Silentalia odontopetalae, Egerkaya cirque, Bolkar Dağları, 3300 m), **i** general view of the Karagöl area (Bolkar Dağları, 2650–3500 m), with sites of all major habitat types, including cliffs, talus slopes with scree, snow patches, wind-swept ridges, and roche moutonné supporting Drabo-Androsactalia vegetation, hydro- and hygrophytic vegetation in and around tarn Karagöl pseudo-alpine vegetation units (mainly rock, scree, meltwater, and wind-swept cushion communities) are rich in local endemics, while the potential to migrate to suitable habitats (no suitable habitats reachable by means of dispersal) is extremely low.

The vertical distribution patterns of the SPAC have been taken from the a. m. phytosociological relevés. Communities were included in the present analysis, if more than 80% of their relevés come from (i) the highest life zones of the selected massifs, i.e., from alpine (respectively pseudo-alpine) and/or subnival elevations; or (ii) moist places (hygrophytic and chionophytic vegetation as well as rock and scree communities demanding humid microclimates) of subalpine and higher altitudes.

Using the above altitudinal limits, all species that occur within the selected vegetation units were grouped according to the following vertical distribution patterns (alphabetical order):

- Group A: Alpine taxa (ca. [2550] 2700–3150 m);
- Group A+S: Alpine + subnival taxa (ca. 3150–3750 m);
- Group L: Asylvatic (high) mountain taxa with occurrences from montane to subalpine elevations, ca. 1600–2650 m;
- Group M: Asylvatic high-mountain taxa with occurrences from oreal to subnival elevations;
- Group P: Pseudo-alpine taxa (ca. [2250] 2350–2550 m; see the explanation above).

Taxa of the groups A+S, A and P are considered to be cryophilic. Together with the hygrophilic taxa, they constitute the core group of the SPAC (Appendix and Fig. 3.4). An "H" denotes pronounced hygrophytic edaphic site conditions; an "H in brackets" [H] taxa of moderately hygrophytic sites.

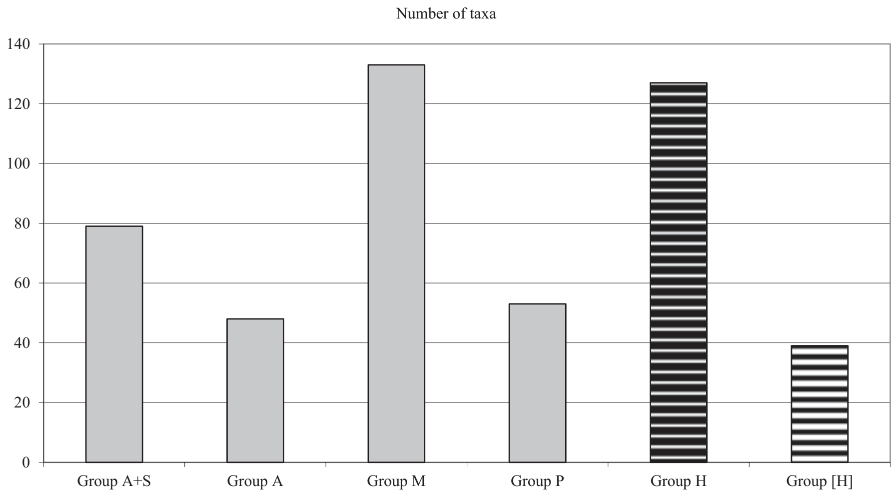

Fig. 3.4 Distribution of 336 cryo- and hygrophilic SPAC among the altitudinal and site-ecological groups [Altitudinal groups: Group **A+S** alpine + subnival, **A** alpine, **M** mountain plants, oreal to alpine/subnival, **P** pseudo-alpine; site-ecological groups: **H** [hygrophilic, [**H**] moderately hygrophilic]

3.4 The High-Mountain Flora and Vegetation of the Western and Central Taurus

The following chapter reviews the flora and vegetation of the Western and Central Taurus Mts., with a focus on those plant communities which are potentially affected by climate change. The SPAC will be mainly addressed in Sect. 3.5.

Kotschy's "Reise in den Cilicischen Taurus über Tarsus" (Kotschy 1858) is the first extensive monograph about the vegetation of the Taurus Mts., makes still today a good reading and is noteworthy for its accurate altitudinal profile. Surveys of the high-mountain vegetation of the Taurus Mts., partly as introductive summary, partly as full regional study, are provided by Akman and Ketenoğlu (1986), Akman et al. (1991), Ayaşlığıl (1987), Eren (2006), Eren et al. (2004), Hein et al. (1998), Kürschner (1982, 1984, 1986a, b, Kürschner et al. (1997, 1998), Louis (1939), Parolly (1995, 1998), Öztürk et al. (1991), Schiechtl et al. (1965) and Schwarz (1936).

The pioneering work of Quézel (1973) remains the basis of the phytosociological framework in the Taurus Mts. A first synopsis of all important formations, and as far as phytosociology is concerned, of all high-ranked syntaxa of the oreal to subnival vegetation, is given by Parolly (2004) and summarized here.

3.4.1 Zonation: Altitudinal Zones and Vegetation

The Taurus Mts. serve as a formidable climatic barrier between the Mediterranean coast and the arid steppe climate of the Anatolian plateau. Especially the different precipitation regime affects the vegetation zonation of the different macroslopes of the mountain chains and the vegetation deviates considerably between the sea-facing (S-facing) and steppe-facing (N-facing) sides. In contrast to the European Alps and the mountains along the Black Sea coast, the Taurus Mts. are characterized by a pronounced summer depression clearly effective up to subalpine elevations. This leads to a generally semiarid vegetation zonation, the so-called Tauric Zonation (Kürschner 1982, 1984), where the mesophytic broad-leaved forests of the montane and oreal complex fail to grow and are replaced by dry coniferous mountain forests (xerophytic forests).

Figure 3.1 summarizes the Tauric Zonation by an idealized N–S profile through the eastern Bolkar Dağları, where an S- and N-facing series can be distinguished. Typical landscapes and habitats are illustrated in Figs. 3.2 and 3.3.

Along the southern incline of the Toroslar, the zonation starts with Mediterranean sclerophyllous forest from sea level to the lower foothills of the mountains (Fig. 3.1, planar to colline zone 1, ca. 0–500 m).

The submontane zone 3 (Fig. 3.1) is normally covered by evergreen and xerophytic coniferous forests sensitive to cold. They are mostly dominated by *Pinus brutia,* display locally *Cupressus sempervirens,* and spread up, limited by temperature, to an altitude of approximately 1000 (1200) m. *Pinus brutia* perfectly indicates Mediterranean climate conditions, those border of distribution largely accords with the 10 °C January isotherm (temperature line).

In the montane zone complex 5 (Fig. 3.1), the forests are physiognomically "evergreen needle-leaved forests resistant to cold." In montane elevations, *Pinus brutia* is replaced by moderately hardy xerophytic coniferous forests, mainly composed of *P. nigra* var. *caramanica*.

Winter-hardy xerophytic forests of *Abies cilicica* (subsp. *isaurica* in the western and subsp. *cilicica* in eastern parts of the Central Taurus, respectively), *Cedrus libani, Juniperus excelsa* and *J. foetidissima* form the zonal vegetation of the oreal belt (zone 5 of Figs. 3.1 and 3.2c) and between 2000 and 2200 (2300 m) the forest line. The forest line is locally often depressed for several hundreds of meters due to intensive anthropogenic impact over the millennia, as is the tree line: Last scattered and gnarled and dwarfed junipers are occasionally found in cliffs as high as 2650 m.

For the forest communities of the area, reference can be made to Akman (1995) and especially Quézel and Pamukçuoğlu (1973) and Quézel (1986).

The subalpine zone 6 (Fig. 3.1) is chiefly marked by extensive and species-rich thorn-cushion communities (ca. 2100–2600 [2700 m]), higher up followed by alpine grassland, scree, and wind-swept cushion communities, which together with rock plants also prevail in the highest altitudes (zones 7–9 of Fig. 3.1, Figs. 3.2 and 3.3). A particular nival zone is not developed in the Western and Central Taurus, since the climatic snowline, to be expected approximately at 3650–3700 m (Kürschner 1982; Schweizer 1972), is only exceeded by a very few summits in the Aladağlar.

The N-facing macroslope is completely influenced by a continental climate as it is typical of the adjoining steppe area of Inner Anatolia. In earlier times, the whole foot of the Taurus Mts. was occupied by open, xerophytic dwarf-shrub communities (*Artemisia* steppe; for a summary, see Kürschner and Parolly 2012), nowadays mostly transferred into farmland (zone 2 of Fig. 3.1).

These *Artemisia* steppes were followed higher up by deciduous, broad-leaved forest (zone 4 of Fig. 3.1), with *Quercus pubescens* subsp. *anatolica* as its dominant. Evergreen species are lacking. The lower tree line, oscillating with the topographic situation between 1000 and 1400 m, is truly hygric, since the expanded drought hampers any forest growth (Louis 1939). Today, such forests are almost completely destroyed, leaving but a few scattered and utterly devastated scrublands or fragments of open forests in sheltered valleys. Nevertheless, oak scrubs and open forests are typical of the margins of Inner Anatolia and border on the steppe region, testifying the once wider distribution of the former forests. Zohary (1973) coined for these broad-leaved forest the term "Xero-Euxine steppe forests," being composed of Euro-Siberian elements in the tree- and shrub-layer and Irano-Turanian steppe elements in the herb-layer (Kürschner and Parolly 2012).

In mid-montane elevations, moderately winter-hardy and winter-hardy xerophytic coniferous forests (zone 5 of Fig. 3.1) gain dominance; *Pinus nigra* var. *caramanica* and *Juniperus excelsa* are the main edificators. *Abies cilicica* and *Cedrus libani* occur rather sporadically, without forming continuous and larger vegetation belts.

Then follow again the subalpine thorn-cushion communities (zone 6 of Fig. 3.1) and the alpine and subnival formations (zones 7–9 of Fig. 3.1) as described above.

3.4.2 Phytogeographic Patterns of Diversity: The Western and Central Taurus as Part of the Tauric System

Concepts The term and geobotanical concept "Tauric System" (Parolly 2004 and in previous papers, e.g., Hein et al. 1998; Parolly 1995, 1998; Parolly and Nordt 2001) was introduced to synthetically characterize the flora and vegetation of an extensive mountain range with the Taurus Mts. in the core. The criteria applied for the definition of the Tauric system accord with those used by Ozenda (1988) for circumscribing "his" Alpic System. The Tauric System represents its south-eastern continuation by comprising the vast mountainous territories between mainland Greece and Iran. This corresponds to the tectonic units of the Hellenids, Taurids, and smaller fractions of the Pontids and Iranids.

Within the range of the Tauric System, the mountain ecosystems enjoy a relatively similar macroclimate expressed in a similar zonation (semiarid zonation; Mediterranean-type high-mountain zonation and climate), support common major syntaxa (mainly at class-level and ordinal-level) composed by species derived from a common Old Mediterranean (Mesogean) floristic stock. In overall, the different parts of the Tauric System share a similar florogenetic and geological past. In florogenetic respects, it is the westernmost mountain system that belongs to the Mesogean Sub-realm in the sense of Quézel (1973), Takhtajan (1986) and Zohary (1973).

A prime characteristic of the Tauric System are the coniferous forests of the montane belt s.l. complex, which are composed of *Pinus brutia, P. nigra* subsp. *nigra* var. *caramanica, Juniperus excelsa* agg., *J. foetidissima, J. drupacea, Cedrus libani* s.l., and especially of the Mediterranean firs (with *Abies cilicica* and *A. cephalonica* as the most important species; cf. Akman 1995; Horvat et al. 1974; Quézel and Pamukçuoğlu 1973; Zohary 1973). These *Cedrus-Abies* forests (Querco-Cedretalia libani, Fig. 3.2c) also outline perfectly the distribution of the Astragalo-Brometalia (oreal to subalpine xerophytic grasslands, dwarf-shrub and thorn-cushion communities on alkaline, ultramafic or schistose soils of Anatolia, the Levant and possibly NW Iran). They mark the core part of the Tauric System and include the wider Western and Central Taurus, Cyprus, and the Lebanon Mts. Within the Tauric System, communities of the Daphno-Festucetales super-class make up the zonal vegetation of the land above the trees (Parolly 2004; see also Barbero et al. 1975; Quézel 1964, 1967).

The phytodiversity within the Tauric System is amazingly high with almost 5000 taxa in Turkey alone and estimated 6500–7000 taxa in all of the Tauric System.

A particular feature of the Tauric System is that it includes mountain ranges, which stretch along the boundaries of two major phytochoria (e.g., S Anatolian Taurus: East Mediterranean vs. Irano-Anatolian [Inner Anatolian] territories). Anatolia as such is known as meeting place of three different phytochoria (Euro-Siberian Region, Irano-Turanian Region, Mediterranean Region; Davis 1965–1985, 1971; Takhtajan 1986).

The vegetation thus harbors and integrates elements of the neighboring regions. This transitional biogeographical position ("melting-pot effect") contributes much to the high speciation potential of that range (Davis 1971; Parolly 2004, Parolly et al. 2010). Additional explanations include the high tectonic, geological, and edaphic diversity, which together with the enhanced climatic diversity at a local scale lead to a wide range of different landscapes and habitat types to be colonized by so many plant species (Davis 1965–1985, 1971). The importance of the very versatile paleogeographical and floral-historical past for understanding the phytodiversity of the area has been emphasized repeatedly (Davis 1971; Ekim and Güner 1986; Eren et al. 2004; Kürschner 1984; Parolly et al. 2010), trying to explain the locally complex patterns of distribution and evolution (paleo- vs. neo-endemics; migration events of various genoelements and chrono-elements; geographical and edaphical vicarism, habitat shifts; for some examples, see below).

Subdivision of the Tauric System Down to province-level, the subdivision of the Tauric System (Fig. 3.4) accords largely with the phytogeographical concepts of Meusel et al. (1965) and Takhtajan (1986). By incorporating the results of field surveys, vegetation studies, and floristic literature, it was possible to establish a finer chorological subdivision of the Tauric System (Parolly 2004) according to the choronomic classification.

The largest part of the Tauric System belongs to the E Mediterranean Subregion (E Mediterranean Province Group sensu Meusel et al. 1965). Crete is treated as part of the Hellenic Province. The central portion of the Tauric System—supporting the *Cedrus-Abies* forest climax—corresponds to a broader S Anatolian Province that comprises four Subprovinces: The Tauric, the Cyprian, the Lebanon, and the Palestine Subprovinces. The naming of the sectors of the Tauric Subprovince follows Parolly (1995) in distinguishing a Lycian, a Pisidian–Isaurian and a Cilician Sector (all three in the Western and Central Taurus) from the Amanos Sector. The existence of a putative Cataonian Sector, adjacent to the Cilician Sector and covering the Anatolian Diagonal, was recently supported (Parolly et al. 2010). By contrast, Davis (1971) suggested ranking the Mediterranean parts of Turkey, viz. W Anatolia, the Taurus Mts. and the Amanos Mts., at district-level (cf. Meusel et al. 1965 for further synonymy).

Between the sectors, the differentiation of the vegetation is mainly at alliance-level, while provinces often bear particular orders. Within these mountain sections, there are portions of mountain ranges and isolated stocks with unique associations and a particular endemism to make them reasonably distinct from the neighboring areas. One is tempted to apply the category of a district to keep Sandras Dağı, Akdağlar, and Beydağları separate from the more W Anatolian mountains encircling Honaz Dağı (Lydian Sector). The territories at the foothills of the westernmost outliers of the Taurus Mts. proper belong in their majority to the adjoining provinces, but the island-like mountains bearing high-mountain vegetation relate it to the S Anatolian Province. Attaching the Alborz Mts. (and all the more the Zagros Mts.) to the Tauric System is at the moment arbitrary and only moderately supported by the present vegetation.

3.4.3 *Phytogeographical Patterning in the Western and Central Taurus*

Chorology: Distribution of the Floristic Elements The phytogeographical spectra of communities or particular mountain ranges (Eren 2006; Eren et al. 2004; Kürschner 1982) reflect the phytogeographical position of the study area along the intersection of two phytochoria, viz. the Mediterranean and Irano-Turanian regions, chiefly represented by E Mediterranean and Irano-Anatolian elements. These chorotypes, partly as biregionals (E Mediterranean–Irano-Anatolian), predominate both in the flora and the majority of the vegetation units, i.e., in all Mesogean units (Hein et al. 1998; Kürschner 1982; Quézel 1973; see also Fig. 3.5).

The prevailing Mediterranean influence becomes even more prominent, if one considers that the bulk of the many endemics of the Western and the Central Taurus are of E Mediterranean (montane) origin (cf. Davis 1965–1985; Davis et al. 1988; Güner et al. 2000).

Generally, the proportion of the Irano-Turanian element increases (i) eastward from the Lycian to the Cilician Sector, (ii) with increasing altitude (Döring 2001; Hein et al. 1998; Kürschner 1982; Parolly 1995; Quézel 1973) and (iii) at moist places (Kürschner et al. 1998).

Whereas life-form spectra reflect the contemporary climatic conditions in displaying one predominant life-form, chorotype spectra may provide some indications

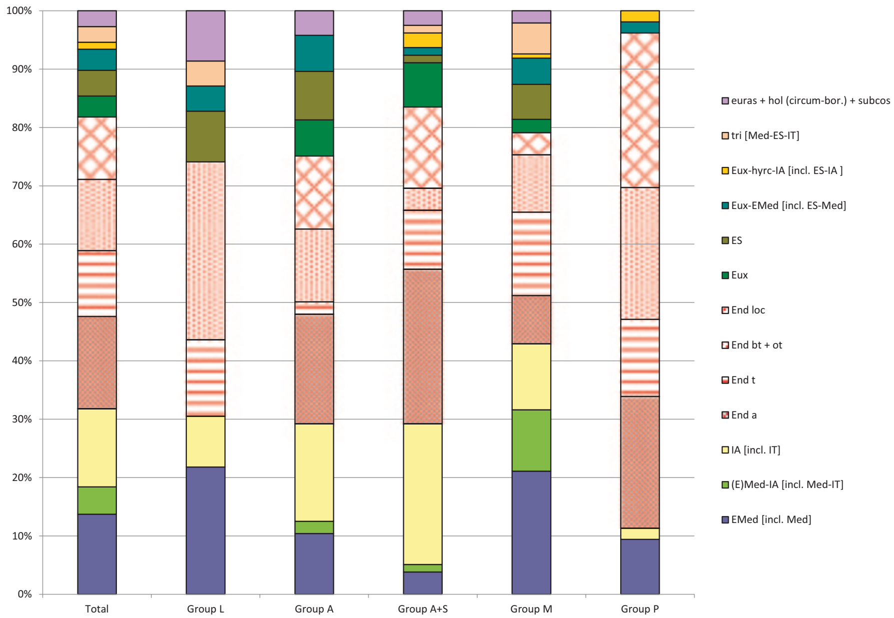

Fig. 3.5 Distribution of the floristic elements among the altitudinal groups

of ancient climates, migration routes, and origin of different elements (Kürschner 1982). For historical reasons (migration along the Anatolian Diagonal during the Quaternary glaciations), the few Euro-Siberian species (including Euxine taxa) are geographically concentrated in the eastern part of the area and edaphically restricted to more or less moist sites.

Local Centers of Diversity Already Davis (1971) has identified the most important centers of diversity (Lycian Taurus, Isaurian Taurus, Bolkar Dağları, etc.) of the study area proper. They often correspond to the present day's Important Plant Areas as mapped by Özhatay et al. (2003).

Neo- versus Paleoendemics Most of the endemic species of the high-mountain vegetation of the Taurus and of Turkey are neoendemics. Only the never glaciated coastal part of the Lycian Taurus (Tahtalı to Bakırlı Dağı) shelters a high number of paleoendemics, including *Asyneuma lycium, A. pulvinatum, Ballota cristata, Dorystoechas hastata, Echinops emiliae, E. onopordon, Globularia davisiana, Lomelosia solymica, Minuartia pestalozzae,* and *Verbascum davisiana* (Davis 1971; Eren et al. 2004; Parolly et al. 2005). However, they partly dwell in lower elevations than studied by the present contribution.

Endemic Genera This is also due for the approximate dozen of endemic genera growing in Turkey, of whom *Crenosciadium* (*siifolium*), *Dorystoechas* (*hastata*), *Olymposciadium* (*caespitosum*), *Oreopoa* (*anatolica*), *Phryna* (*ortegioides*), *Sartoria* (*hedysaroides*), and *Thurya* (*capitata*) are more or less associated to the Taurus range. Among them, *Oreopoa anatolica* is the only high-mountain plant in a strict sense (Parolly and Scholz 2004).

Further Patterns of Endemism Endemism within the Taurus range and in adjacent Inner Anatolia is often clustered, i.e., there are many groups of plants displaying numerous, often vicarious or corresponding endemics with predominantly smaller to extremely narrow distribution. Good examples are provided by *Acantholimon, Astragalus* sect. *Hololeuce, Campanula* sect. *Quinqueloculares, C.* sect. *Rupestres, C.* sect. *Tracheliopsis, Centaurea, Origanum, Phlomis* sect. *Dendrophlomis, Sideritis* sect. *Empedoclea* and *Verbascum* p.p. (Davis 1965–1985, 1971; Davis et al. 1988; Güner et al. 2000).

The mountain vegetation of the phytogeographical sectors of the Western and Central Taurus shows at the same time a major principle of the syntaxonomy and phytogeographic pattern of the Mesogean Tauric System: Its communities are often characterized by complexes of vicarious and corresponding species. Analyzing their distribution patterns and species differentiation is a keystone in understanding evolution processes in these vegetation units. Many genera contribute with two, ideally three allopatric (or at least allotropic) taxa to the composition of the high-mountain vegetation of the study area. These species often differentiate the vegetation of neighboring mountains. A few examples may illustrate this:

The SW Asian scree-creeping *Heldreichia,* comprising a single polymorphic species, *H. bupleurifolia,* with four largely geovicarious subspecies, is in this context the best understood group (Parolly et al. 2010). Geographical areas with higher morphological and molecular diversity correspond to the generally accepted speciation and diversity centers of the Taurus range. Inter-pluvial migration events between isolated mountain ranges may have contributed to the morphological and genetic diversity within *Heldreichia*.

The genus *Lamium*—I am in its taxonomy explicitly not following Güner et al. (2012)—plays a similar important role on scree and *L. eriocephalum* subsp. *eriocephalum* (*L. amplexicaule* group) is a dominant of the screes of the Cilician Taurus. In the Pisidian and Isaurian Taurus it is replaced by its subsp. *glandulosidens*. In the Western Taurus, the corresponding *L. cymbalariifolium* agg. (*L. garganicum* complex) occurs. At the westernmost edge of the Taurus (Honaz Dağı, Baba Dağı), the *Lamium cymbalariifolium* scree (Lamietum cymbalariifolii) of the Lycian Taurus is replaced by a vicarious *L. microphyllum* community. Other closely related species (e.g., *L. sandrasicum*) add much to the regional diversity by colonizing different substrates (serpentine) and habitats (rocks and gullies) within the more or less same range (Parolly 1995, 2004).

Similar habitat shifts are also observed in *Scorzonera* sect. *Nervosae*. This mainly Irano-Anatolian group shows traits of secondary evolution in the Taurus Mts. (Parolly and Kilian 2003). In the montane belt of S Anatolia, rosulate hemicryptophytes prevail on rocky slopes and in open forests. A pair of vicarious species, formed by *S. karabelensis* and *S. ulrichii*, grows fairly localized on limestone in open, montane black pine forests of the Lycian and Isaurian Taurus, respectively. By contrast, the pseudovicarious *S. pisidica* is a serpentinophyte linked to barren landscapes of the Lycian Taurus once occupied by pine forests (Kilian and Parolly 2002; Parolly and Kilian 2003). Further in east, the widespread and less specialized *S. cinerea* can be recorded in a wide range of open habitats and on various substrates up to subalpine elevations. Here, rosulate hemicryptophytes or pulvinate chamaephytes of *Scorzonera* sect. *Nervosae* and *S.* subgen. *Pseudopodospermum,* especially of the S. *suberosa* group (*S. sandrasica*; *S. szowitzii, S. phaeopappa*) mark some grasslands and thorn-cushion communities. Higher up, in the Drabo-Androsacetalia belt, they are replaced by the pulvinate chamaephytes of *Scorzonera* sect. *Pulvinares* (*S. sericea* group) such as *S. pygmaea, S. rigida* and *S. sericea.*

Similar patterns, underpinning the tripartite subdivision of the study area, are found within the scree flora in *Aethionema, Galium, Nepeta, Noccea, Ricotia, Scrophularia* and *Veronica* (Parolly 1995) and within the chasmophytes in *Omphalodes luciliae, Valeriana* spp. (Hein et al 1998; Parolly and Eren 2006; Sağlam 2010) or in *Potentilla* sect. *Crassinervis* (Parolly and Nordt 2002).

3.4.4 *Survey of the High-Mountain Vegetation of the Western and Central Taurus, with a Focus on Plant Communities Potentially Affected by Climate Change*

3.4.4.1 Lithophytic Vegetation

Scree Vegetation

Extensive scree- and talus slopes are an outstanding physiognomic feature of the high mountain ranges of the Taurus Mts. These mobile scree and instable raw lithosols are occupied by very open scree plant communities classified within the Lamietalia cymbalariifolii (Western Taurus) and Heldreichietalia orders (Heldreichietea; for a monograph, see Parolly 1995, 1998). The scree communities are highly diverse (ca. 250 species recorded in the plots), endemic-rich and chiefly composed of creeping hemicryptophytes and rhizome geophytes adapted to burial, and an often considerable proportion of bulbous geophytes which move with the unstable substrate. Depending on the mobility and the structure and the contents of fine soil and the altitude, various associations have been described from the Taurus Mts.

The Lamietalia cymbalariifolii interpose between the Heldreichietalia and the Drypetea spinosae of the Balkans and NW Anatolia. The Scrophularion depauperatae (4 associations, including an unpublished association) is the scree alliance of the Batı Toroslar. The Scrophularion myriophyllae (2 associations + 2 unpublished communities) comprises the limestone-screes of the western Orta Toroslar. In the eastern part of the Central Taurus, two altitudinally arranged alliances occur. The Scrophularion rimarum (4 associations) is centered in the subalpine belt, inhabiting relatively coarse moving mounds and screes. The Jurinellion moschus (five associations) occupies cryoturbated, finer structured and partly stabilized talus slopes of the upper alpine and subnival belt of the high eastern Central Taurus (Bolkar Dağları and Aladağlar).

A study of the dispersal biology indicates, besides enhanced proportions of clonal reproductive effort, the significance of anemochorous and autochorous mechanisms within the plant communities. While anemochory is an important and frequent principle of dispersal in mountain ecosystems, the high percentage of autochorous plants proved to be specific to lithophytic habitats and correlated with the slope-mobility and the dominating shortage of fine soil. Especially in subalpine, active and coarse screes with few finer material autochory reaches very high percentages. Under the unfavorable conditions of such habitats, the deposition of diaspores next to the mother plant (achory) is a successful strategy against the loss of diaspores and ensures the best establishing conditions.

Heldreichietea Communities Probably Affected by Effects of Climate Change Scree communities of the western part of the study area are mainly expected to be least concerned by effects of global warming. For most of these species assemblages, a possible joint upward migration is likely in all higher mountain ranges. However, this does not hold for the Lamietum microphylli (Baba Dağı, Honaz Dağı) and local races of the

Lamietum cymbalariifolii (Tahtalı Dağı and adjoining mountains in the Beydağları), which grow on N-facing scree in cirques under pseudo-alpine conditions. A larger part of their diagnostic species rank among the SPAC.

Two of the four associations of the Scrophularion rimarum alliance of the Cilician Taurus, centered in subalpine elevations, can reach the alpine belt (growing up to 3000 m) such as the Prenantho glareosae-Scrophularietum rimarum. The eponymous *Lactuca (Prenanthes) glareosa* listed among the SPAC (Appendix), is a local endemic of the Bolkar Dağları with a recent, anthropogenic range extension to the Aladağlar (Parolly 2006). The chionophytic Anthrisco kotschyi-Aurinietum cyclocarpae adds further species to the list. It inhabits moist, stabilized screes near snow-beds with a well-developed layer of silt and finer material. It occurs in the alpine belt of the eastern Orta Toroslar and was studied in the Bolkar Dağları. The snow-free period of the sites lasts hardly three months. Affinities to the Trifolio-Polygonetalia and Drabo-Androsacetalia vegetation are evident.

The scree plant communities of the highest elevations are certainly units to be affected first and most severely by global warming. Stands of the five associations constituting the alpine–subnival Jurinellion moschus grow on cryoturbated, mobile to stabilized mounds, talus slopes, moraines, block glaciers and screes up to 3600 m in the eastern Orta Toroslar. At these altitudes, diurnal, intensive freeze–thaw cycles result in unstable, immature substrata and micro topography, solifluction lobes and patterned ground. Compared with the screes of other units, the fine soil layer is better developed.

Besides "normal" mesophytic scree plant communities (e.g., Tulipo humilis-Jurinelletum moschus, Heldreichio-Isatietum frigidae), the alliance also includes hygrophytic units. In the highest altitudes of the Cilician Taurus, the Cerastio cerastoidis-Minuartietum rimarum forms the vegetation of the rock-glacier fronts, moraines, and stable patches in moist screes with a long snow-cover. The presence of water leakage and, compared with screes, a well-developed and easily visible layer of silt and finer material, are among the most prominent edaphical factors. The Cerastio cerastoidis-Minuartietum rimarum shows many affinities to moist Drabo-Androsacetalia plant communities.

The Jurinellion moschus is especially rich in endemics, most of them are confined to the alpine belt and hence species possibly concerned by climate change (SPAC, Appendix).

Chasmophytic Vegetation

The scenery of the higher elevations of the Taurus Mts. (Figs. 3.2b, j, 3.3a–c, h–i) displays over vast ranges a rugged profile, with bizarrely shaped rocky ridges and cliffs towering over high valleys, gorges, cut hundreds of meters deep into various bedrock, and ledges supporting sheltered half-caves. These rocks provide a wide range of chasmophyte habitats (sloping rock, overhanging rock, vertical rock, step crevices; Davis 1951; Hein et al. 1998) and harbor an extremely diverse chasmophytic flora. Already the first monograph on the rock flora and vegetation of higher elevations of the Toroslar (Hein et al. 1998) sampled more than 220 vascular plant taxa by the relevés. Ca. additional 120 species have been recorded in the plots of a complementary study aiming to close some geographical gaps (Parolly, unpublished).

The Silenetalia odontopetalae order (Asplenietea trichomanis) classifies the chasmophytic, predominantly basiphytic vegetation of rock faces, fissures, and ledges of NW, W, and S Anatolian and adjoining Levantine mountains (Quézel 1973; Parolly 2004). It is remarkable that there is no particular serpentine rock vegetation in the Taurus Mts. at association- or alliance-level. All stands presently studied represent fragments of the known alliances (the local stands feature a few serpentinophytes only and are otherwise negatively marked by the absence of most of basiphytic character species).

The rock vegetation of the Western and Central Taurus groups into five phytogeographically and ecologically well-differentiated major units (alliances).

Throughout all of the range, stands of the hygro- to mesophytic Campanulion cymbalariae (eight communities, three of them unpublished) dwell at cool, shady and humid places. They are physiognomically dominated by hemicryptophytes and chorologically distinct by enhanced proportions of Euro-Siberian taxa. The Campanulion cymbalariae stands against four mesophytic to xerophytic alliances largely made up by chamaephytes and predominately developed at warm sites under more sunny conditions.

Phytogeographically, the xerophytic rock vegetation indicates a subdivision of the study area into three parts and a distinct altitudinal zonation. The xerophytic units are largely composed of a great proportion of endemics and E Mediterranean and Irano-Turanian chorotypes of mono- and bioregional distribution patterns, thus indicating the Old Mediterranean (Mesogean) origin of the saxatile flora of the Tauric System.

The Silenion odontopetalae marks in montane to subalpine elevations the Lycian Sector, the Campanulion isauricae the Pisidian and Isaurian Taurus Sector and the Onosmion mutabilis the Cilician Sector. They comprise a total of ca. 20 plant communities (in ca. seven associations, two of them unpublished; see Hein et al. 1998).

In the high eastern Central Taurus (Bolkar Dağları and Aladağlar), the high alpine–subnival Drabion acaulis replaces above (2700) 2900 m the Onosmion mutabilis (Hein et al. 1998).

Silenetalia Odontopetalae Communities Probably Affected by Effects of Climate Change The hygro-/or cryophylic communities of Campanulion cymbalariae and Drabion acaulis alliances are prime candidates for being considered here. The Omphalodetum cilicicae (Hein et al. 1998) and Aubrieto canescentis-Omphalodetum luciliae (Sağlam 2010) and their eponymous character species display a wide altitudinal range, have many localities, and hence may not be at risk in the whole range, but may well be threatened on mountains such as Honaz Dağı, where the latter community forms part of the pseudo-alpine vegetation.

Stands of the Drabion acaulis (Drabetum acaulis, including the subnival subass. typicum and the alpine subass. saxifragetosum kotschyi) grow up to more than 3600 m. More than 15 vascular plant species have been recorded dwelling on rocks at altitudes higher than 3500 m, including *Draba acaulis* (Fig. 3.3h), *Gnaphalium leucopilinum, Minuartia rimarum, Potentilla pulvinaris* (two subspecies), *Saxifraga kotschyi*, and *Veronica kotschyana*. The proportion of endemics exceeds the 60 % level (Hein et al. 1998).

In the Western Taurus (Silenion odontopetalae), three pseudo-alpine and one alpine vegetation units may be concerned, viz. the yet undescribed stands with *Galium aretioides* on Honaz Dağı and three subassociations of the Aethionemo lycii-Laserpitietum petrophili. The saxifragetosum adenophorae subassociation (Hein et al. 1998) is the only alpine development within the alliance and bound to the N-facing cirque system on Kızlar sivrisi. *Asplenium tadei* (second known locality) and the largely chionophytic *Poa akmanii,* endemic of the Western Taurus and the Arc of İsparta (Eren et al. 2004; Hein et al. 1998), are the most important floristic records coming from here. The vegetation of the cliffs and rock fissure communities of Bakırlı Dağı and the neighboring summits harbor the other two communities. The Aethionemo lycii-Laserpitietum petrophili subass. saxifragetosum luteoviridis characterizes moderately shady and humid cliffs with the Euxine *Saxifraga corymbosa* (*S. luteoviridis*) as differential species of the Campanulion cymbalariae. The arabidetosum lycicae subassociation is confined to rocks along the wind-swept ridges, and besides the eponymous taxon, differentiated by an enhanced number of Drabo-Androsacetalia species (Eren et al. 2004; Hein et al. 1998; Parolly and Hein 2000).

Within the mostly xerophytic Campanulion isauricae, the Geranio glaberrimi-Nepetetum concoloris subass. doronicetosum cacaliifolii, known from the subalpine belt (2100–2500 m) of the Geyik Dağları, is a putative candidate unit as being restricted to particular hygric site conditions. Most of its stands dwell in broad and deep clefts at the steep basis of high and shady, N-facing rock walls situated in cirques or deep dolines. Some stands develop at the entrance of the frequent grottos. They cover the bottom and the vertical walls of the cavities opened in the somewhat porose limestone. At flowering time, the stands of the community are still situated next to long-lasting snow-fields nearby the walls.

There are further more sciadophytic communities such as the association à *Erodium pelargonifolium* et *Silene capillipes* and the association à *Valeriana speluncaria-Campanula leucosiphon*, displaying elements of the "Balmenflora" (dwellers of half-caves and grottos) within the alliance (Quézel 1973). However, they occur mainly in the montane zone and are not treated here. By contrast, the *Valeriana speluncaria* community (Hein et al. 1998) may be better re-classified within the Omphalodetum luciliae and the hygrophytic Campanulion cymbalariae alliance.

The Galio cani-Scrophularietum kotschyanae represents the moist wing of the Onosmion mutabilis. The diagnostic species of the association are part of the "Balmenflora" of the Cilician Taurus. The Irano-Turanian *Scrophularia kotschyana* is a malacophyllous plant with large, soft leaves and reported from "shady, sheltered cliffs, crevices, ledges, ruins, waste places, 600–2400 m" (Lall and Mill 1978). It is mainly spread through Central, S, and NE Anatolia, and Georgia (Caucasus). In the eastern Orta Toroslar it is strictly confined to the rocks of canyons and grottos. In the canyons of the Aladağlar, the association covers half-caves excavated by glacial and fluviatile activities at the roots of the high-towering limestone walls at oreal altitudes (1700–2100 m). In the Bolkar Dağları, the stands of the association occur in the subalpine belt (ca. 2450 m) on conglomerate rocks forming deep grottos; those extremely shady headwalls support well-developed stands of the Galio-Scrophularietum. A constant microclimate with high humidity is the limiting site factor for the community.

3.4.4.2 Oromediterranean High-Mountain Vegetation

Subalpine Thorn-Cushion Communities, Dwarf-Shrub Communities, and Limestone Swards

Gappy limestone swards (Fig. 3.2a), dwarf-shrub communities and thorn-cushion communities are the most prominent and abundant formations of the SW Asian high-mountain vegetation (Barbero et al. 1975; Kürschner 1986a, b) and the dominant vegetation of the subalpine belt of the Taurus Mts. (Ayaşlığil 1987; Düzenli 1976; Duman 1990; Eren 2006; Eren et al. 2004; Quézel 1973). The thorn-cushion communities and limestone swards of the subalpine belt are normally species-rich stands with clear Mediterranean links, including a moderate number of endemics of E Mediterranean origin (ca. 15–20 %). The influence of the Irano-Turanian element is fairly low (<15 %). The proportion of tragacanthic species (Figs. 3.2e, j) varies greatly with altitude, exposure, and pedology (substrate, fine soil content and thus the water capacity). Physiognomically, tragacanthic subshrubs and caespitose graminoids dominate, while a few annuals and many geophytes colonize the gaps. Many stands of limestone swards (Fig. 3.2a) are nothing but initial dwarf-shrub and thorn-cushion communities establishing themselves on stabilized scree slopes or old rock slides.

All communities of the southern macroslope of the Taurus Mts. can be grouped into a single Astragalo-Brometalia order, disregarding of the substrate type (limestone, schist or serpentine). They represent the zonal vegetation of the subalpine belt.

On the steppe-facing side, the situation is more complex at places, where the forest vegetation has been degraded. Here, the steppe communities of the mountains of the Inner Anatolian highland (Asperulo phrygiae-Thymenetalia chaubardii suborder, Onobrychido armeni-Thymetalia leucostomi) encroach into the stands of the Astragalo-Brometalia. For descriptions of the Onobrychido armeni-Thymetalia leucostomi vegetation, see Akman (1990), Akman et al. (1984, 1985, 1991, 1996), Ketenoğlu et al. (1996), Kürschner and Parolly (2012) and Ocakverdi and Oflas (1999). The distinction between upland steppe vegetation (Asperulo phrygiae-Thymenetalia chaubardii, ca. [1300 m] 1500 to high montane elevations; Akman et al. 1991) and the zonal Astragalo-Brometalia communities of the subalpine belt of the Tauric System remains still unclear (Kürschner and Parolly 2012; Parolly 2004).

Based on published and unpublished relevés (Döring 2001; Eren et al. 2004; Kürschner 1986a, b; Tolimir 2001), ca. 12 often intergrading and partly substrate-specific units may be distinguished within three alliances (Tanacetion praeteriti in the Western Taurus, Agropyro tauri-Stachydion lavandulifoliae in the Central Taurus, Thuryion capitatae on serpentine) and one Astragalo-Brometea order (Parolly 2004).

All these limestone swards, dwarf-shrub communities, and thorn-cushion communities show principally an enhanced proportion of ballochorous species, which thorny *Astragalus* spp. being important components, and often species with diaspores adapted to ant-dispersal (myrmekochory).

Communities Probably Affected by Effects of Climate Change Effects of climate change on the xerophytic units and flora are generally negligibly small, since upward shifts appear in most cases possible. However, there is one notable exception, viz. the Thuryion capitatae communities from the Sandras Dağı serpentine area, with an extremely high percentage of endemism in pseudo-alpine situation.

Vegetation of Wind-swept Mountain Habitats, Zonal Alpine, and Subnival Vegetation (Drabo-Androsacetalia)

In the highest elevations, mat-forming and cushion-forming communities (Figs. 3.3a, b) prevail under different edaphical conditions in various inclinations. Physiognomically, small pulvinate, creeping, and suffruticose chamaephytes dominate together with caespitose hemicryptophytes. The proportion of thorn-cushions is reduced, although *Onobrychis cornuta, Astragalus angustifolius,* and *Acantholimon ulicinum* can reach the highest cover in some communities. The vegetation cover of most of these stands is low, ranging in average from (20) 30 to 50 (70)%, but the species diversity is high with 25–50 species recorded within 10 m^2 plots (Eren et al. 2004; Parolly, unpublished data). Phytosociologically, this vegetation type is summarized under the Drabo-Androsacetalia order (Quézel 1973). They make up the “zonal” vegetation of the alpine to subnival belts on alkaline, often heavily cryoturbated substrates. Extrazonal, often small-scaled outposts are confined to wind-swept rocky flats and exposed ridges in oreal to subalpine elevations. More than 380 taxa have been noted in the Drabo-Androsacetalia plots studied.

The range of the orders tapers to the NW to include the Uludağ as home of the monotypic, ill-defined Alopecurion lanatae (Quézel and Pamukçuoğlu 1973). In the Taurus Mts., a subdivision of the Drabo-Androsacetalia into three major groups, exactly reflecting the main phytogeographic pattern found there (Lycian, Pisidian–Isaurian, and Cilician Taurus Sectors) and outlined in earlier papers (Hein et al. 1998; Parolly 1995, 1998, 2004) is evident. In core, these vegetation units correspond to Quézel’s alliances (Paronychion lycicae, Silenion oreadis, Silenion pharnacaeoidis), which all are in need of corrections in their geographic delimitation and in the much enhanced species inventory (also at ordinal-level).

In terms of dispersal biology, the Drabo-Androsacetalia are marked by the high proportion of cyclochorous species, such as many herbaceous Astragali and other Fabaceae with inflated calyces or Asteraceae, such as *Centaurea drabifolia,* which disperse the whole capitulum. By contrast, the Astragalo-Brometalia order, has principally an enhanced proportion of ballochory, which the thorny Astragali being important components.

Drabo-Androsacetalia Communities Probably Affected by Effects of Climate Change Due to the altitudinal range colonized, all units of Drabo-Androsacetalia vegetation are threatened as representing the only quasi zonal cryophilic vegetation with a larger-scaled distribution. It may be assumed that the extrazonal patches in lower (subalpine) elevations would be affected first, together with those units forming the pseudo-alpine vegetation of the lower mountain ranges (e.g., the *Seseli hartvigii* community in the eastern Beydaglari) in the western part of the study area (Eren et al. 2004; Parolly and Nordt 2001).

Even within the diverse high-mountain flora of the Taurus Mts., the Drabo-Androsacetalia communities stand out by their great number of endemics and high rate of endemism. Sixteen out of 24 communities distinguished, display rates above 40 % and 7 units slightly below or above 50 %.

In the highest elevations of the Cilician Taurus, patchily scattered *Kobresia humilis* turf has been sampled on moist alpine to subnival rock ledges situated in cirques (Döring 2001; Parolly 2004). Although better treated as a floristically and physiognomically distinct vegetation class, its SPAC are dealt here for practical reasons in the frame of the Drabo-Androsacetalia vegetation. The *Kobresia* turf of the Taurus is fairly species-poor and bears many Alpic–Asian floristic links (with the Caucasus and especially Central Asian mountain ranges). The small patches found grow on moist rocky outcrops; at their dryer margins, they merge into the surrounding Drabo-Androsacetalia vegetation.

Hygrophytic to Mesophytic Vegetation of Snow-Beds Snow-Patches, Meltwater Runnels, Dolines, and Trampled Turf

Snow-patches developed in dolines, meltwater runnels, and similar chionophytic sites provide special, at least temporarily moist environments for plants in otherwise dry surroundings. In their majority, the vegetation of such damp places can be classified into the Trifolio anatolici-Polygonetalia arenastri order (Kürschner et al. 1998; Parolly 2004). In spite of being very rich in geophytes and hemicryptophytes, they represent the damp wing of the xeric thorn-cushion and dwarf-shrub communities (Astragalo-Brometea) and not an independent Trifolio-Polygonetea (Quézel 1973) vegetation class (Parolly 2004).

The snow patch and meltwater communities of the Western Taurus and the adjacent Pisidian and Isaurian Taurus form a particular Thlaspion papillosi alliance within the Trifolio-Polygonetalia. The alliance comprises two associations (Muscari bourgaei-Ornithogaletum brevipedicellati, Fritillarietum pinardii) and one rankless community. The Bolanthion frankenioidis (Quézel 1973), occurs in the same range and unites of the mainly mesophytic “pelouses rases” (carpet turfs) in dolines, which are quite different from the chionophytic communities in floristic, physiognomical and ecological respects.

The hygro- to mesophytic vegetation of dolines, turfs, snow patches, and meltwater runnels of the Cilician Taurus belongs mostly to the Trifolio-Polygonion alliance (Quézel 1973), from where only Trifolio-Polygonion base communities have been hitherto recorded (Kürschner et al. 1998). By contrast, the high-alpine and subnival meltwater communities of this area (Bolkar Dağları and Aladağlar) are attached phytosociologically to scree plant communities (Jurinellion moschus, Heldreichietea).

Communities Probably Affected by Effects of Climate Change Being hygrophytic and often chionophytic, the sensitiveness against changes is obvious. All 15 communities known were considered and the list of SPAC, both from stands on limestone and serpentine, is fairly long (Appendix and Fig. 3.6).

3.4.4.3 Azonal Hydro- and Hygrophytic Vegetation

Besides the Trifolio-Polygonetalia, there is a remarkably wide range of hydro- and hygrophytic vegetation in the Taurus Mts., all with a predominantly Euro-Siberian outline and main occurrences in the Euxine part of the country. This surprising diversity is found in spite of the often untoward surface conditions in the karstic limestone areas, which however cause their patchy and small-scaled occurrences. These green grounds in xeric surroundings attract since times men and domestic animals (Fig. 3.2b). An often enormous grazing pressure makes many places unattractive for studies, but they harbor a good deal of rare and interesting species. Studying and monitoring the community structures and degradation gives us a key tool for qualifying the human impact on mountain ecosystems. The wetland communities can be grouped into at least six classes (Charetea fragilis, Potametea, Phragmito-Magnocaricetea, Molinio-Arrhenatheretea, Montio-Cardaminetea, Scheuchzerio-Caricetea fuscae; Hein et al. 1995; Parolly 2004; Raab-Straube 1994).

Depending on the geological substrate, the vegetation of transitional mires, low-sedge fens, and bog hollows of the Scheuchzerio-Caricetea fuscae is traditionally grouped into three orders. Due to the prevalent geological situation, the (subalpine) alpine stands of the Taurus Mts. belong to the basiphytic Caricetalia davallianae order (Hein et al. 1995; Raab-Straube 1994). The bryophyte- and herb-rich vegetation of springs and edges of fast-running high-mountain rapids (Montio-Cardaminetea) was hitherto sampled as vegetation complex with the Scheuchzerio-Caricetea fuscae only. The limits between the two classes and contact communities are locally still to be clarified. The Montio-Cardaminetea of the Taurus are represented by small mossy patches along runnels and springs.

All of these hygrophytic communities are mainly composed of Euro-Siberian taxa, with Irano-Anatolian species being a distant second. In most units, a fairly large number of species of Balkan, Euxine, Caucasian, or Hyrcano-Euxine distribution pattern occurs.

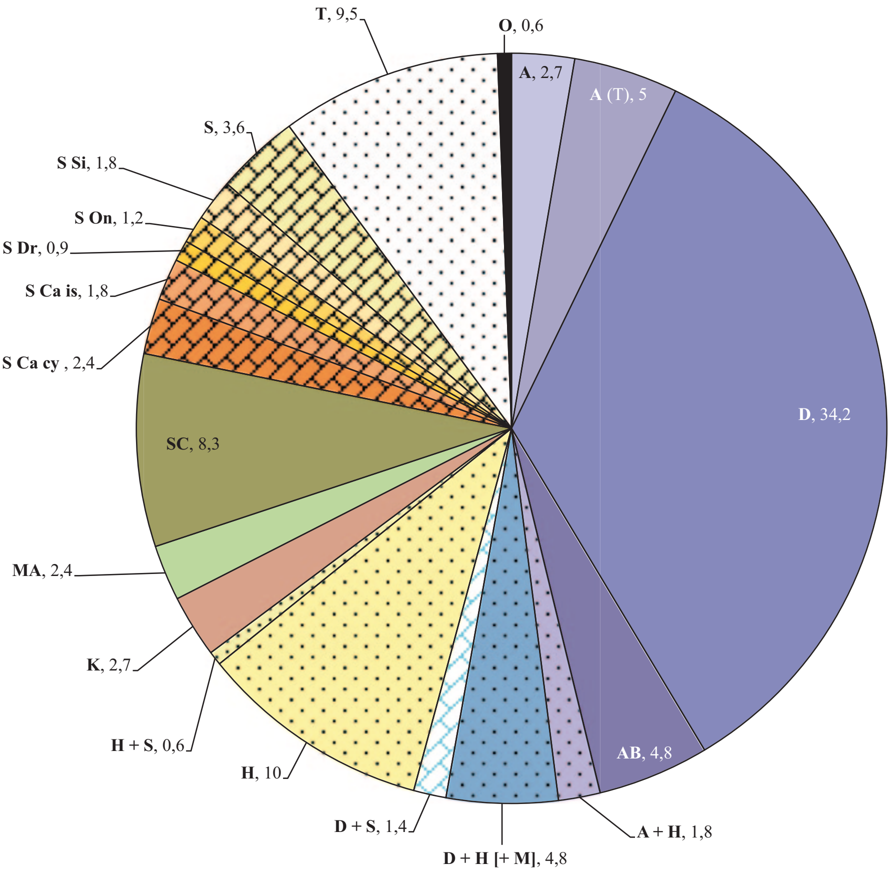

Fig. 3.6 Distribution of the SPAC among the major vegetation units (fore explantion of phytosociological units, see Chap. 3.4). Abbreviations: **A** Astragalo-Brometalia (Tanacetion praeteriti) [+Trifolio-Polygonetalia], **AB** Astragalo-Brometea, **A+H** Astragalo-Brometalia + Heldreichietea, **A (T)** Astragalo-Brometalia (Thuryion capitatae), **D** Drabo-Androsacetalia, **D+H** Drabo-Androsacetalia + Heldreichietea [+ M Montio-Cardaminetea], **D+S** Drabo-Androsacetalia + Silenetalia odontopetalae, **H** Heldreichietea, **H+S** Heldreichietea + Silenetalia odontopetalae, **K** Kobresia humilis turf [incl. D+T Drabo-Androsacetalia + Trifolio-Polygonetalia], **MA** Molinio-Arrhenatheretea; **O** Others, **S** Silenetalia odontopetalae [+ Asplenietea trichomanis], **S Ca cy** Campanulion cymbalariae (Silenetalia odontopetalae), **S Ca is** Campanulion isauricae (Silenetalia odontopetalae), **S Dr** Drabion acaulis (Silenetalia odontopetalae), **S On** Onosmion mutabile (Silenetalia odontopetalae); **S Si** Silenion odontopetalae (Silenetalia odontopetalae), **S** Silenetalia odontopetalae [+ Asplenietea trichomanis], **SC** Scheuchzerio-Caricetea [+ Montio-Cardaminetea], **T** Trifolio-Polygonetalia [incl. Trifolio-Polygonetalia + Scheuchzerio-Caricetea]

Communities Probably Affected by Effects of Climate Change All communities will doubtlessly be affected by a changing water regime and drastically reduce the diversity of these rare moist spots harboring many Euro-Siberian species (s. above) growing at interesting range outposts. The few endemics occurring in low-sedge fens and flushes, such as *Gentiana boissieri*, are more closely associated with *Kobresia humilis* turf.

3.5 The High-Mountain Plants of the Western and Central Taurus in a Changing Environment: Results and Discussion

This is the first study aiming to identify plant communities and species affected by climate change in the Taurus Mts. and in Turkey. While the ca. 75 plant communities possibly threatened by climate warming have been introduced and discussed in Sect. 3.4, the results of evaluating the phytosociological tables in taxonomic respects are shown here.

In total, 620 upland taxa have been classified into the altitudinal and site-ecological groups (groups L, M, P, A, A+S, and [H] and H). The 336 taxa, constituting the high-mountain plants proper (excluding the xero- and mesophytic taxa of group L), are listed the in Appendix, which can be seen as a kind of prewarn list. Only a fraction of these species is included in the Red Data Book of Turkish plants (Ekim et al. 2000). Figure 3.1 summarizes the distribution of the number of the taxa within the groups.

The plots of the study area harbor 127 cryophilic taxa (groups A plus A+S), which are mainly linked to vegetation units of the alpine life zone sensu Körner (2003). In a similar way, the 53 taxa (of a total of 75 taxa recorded) of group P are closely bound to the highest elevations of mountains with pseudo-alpine paraclimax vegetation on their summits; they are indicated by an (x) in the Appendix. The groups A, A+S, and P thus summarize the 180 vascular plant species exclusive to the highest life zone of the Western and Central Taurus.

In the Western and Central Taurus, ca. 150 vascular plant taxa (groups M, A, A+S) reach elevations of more than 3000 m (3200 m). Approximately 30 of them dwell above 3500 m, including *Alopecurus textilis* (to 3600 m), *Androsace multiscapa* (to 3600 m), *Arenaria balansae* (to 3680 m), *Crepis frigida* (to 3600 m), *Cystopteris fragilis* (to 3660 m), *Galium cilicicum* (to 3600 m), *Jurinea moschus* (to 3630 m), *Lamium eriocephalum* subsp. *eriocephalum* (to 3640 m), *Potentilla pulvinaris* subsp. *argentea* (to 3670 m) and *Thymus brachychilus* (to 3680 m).

Above 3500 m, the last fragments of structured stands of rock and scree communities stop to occur. At sheltered places, sun-exposed crevices or small and gently inclined scree spots, scattered individuals of vascular plants grow even higher up: Seven species have been recorded at or slightly above 3700 m (Parolly 1995), viz. are *Arabis caucasica* subsp. *brevifolia* (3720 m), *Cerastium cerastiodes* (3700 m), *Draba acaulis* (3723 m, Engin Tepe summit), *Minuartia rimarum* (3700 m), *Noccea sintenisii* subsp. *crassum* (3710 m), *Saxifraga exarata* (3719 m) and *Veronica kotschyana* (3710 m).

A total of 167 taxa entered the prewarn list (Appendix) as "hygrophilic" in a wider sense (groups [H] or H) and being associated with moist site conditions; 60 of them occur also above 3000 m (39 in H, 21 in [H]), often representing cryo-hygrophilic taxa. The core group of H comprises chionophytes and plants of shady and humid rocks. For brevity, reference can be made to the chorological spectra discussed by Kürschner et al. (1998) and Hein et al. (1998), respectively. The further analysis of the data available focuses on the endemic taxa.

Distribution of Endemic SPAC Among the Vegetation Units Figure 3.6 shows the distribution of 336 taxa among the major syntaxa, which often correspond to particular habitat types. The results come to no surprise; more than half of all species listed grow in Astragalo-Brometea communities (183 taxa = 54.9 %), which form in physiognomic respects dwarf-shrub and thorn-cushion communities as well as xerophytic grasslands. The bulk of them (36 %) occur mainly within Drabo-Androsacetalia communities, which are the dominant vegetation type of the alpine and subnival elevations. Hygrophytic Astragalo-Brometea communities, viz. the stands along meltwater runnels and making up the doline turf (Trifolio-Polygonetalia), are represented by 29 taxa (8.6 %). Scree (Heldreichietea), and rock plants (Silenetalia odontopetalae) contribute with further ca. 10 %, respectively 12 % to the spectrum. All other phytosociological units are considerably less diverse.

Especially the SPAC, which are associated with Mesogean syntaxa, making up the core of the communities of the Taurus System, show often narrow distribution patterns (cf. Appendix and Davis 1965–1985; Davis et al. 1988; Güner et al. 2000; Parolly 2004; Quézel 1973). Among them, the rate of endemism is above 45 %, such as in Astragalo-Brometalia (75 %), Drabo-Androsacetalia (56 %), Heldreichietea (52.9 %), Silenetalia odontopetalae (57.5 %) and Trifolio-Polygonetalia (48.3 %), while some of their subunits boast in ever higher percentages of endemic species, e.g., 86.7 % in the serpentine-colonizing Thuryion capitatae (Astragalo-Brometalia) and 100 % within the Campanulion isauricae and Drabion acaulis (Silenetalia odontopetalae). These rates of endemism obtained from evaluating the taxon list of the Appendix are in line with the data from chorological analyses of high-mountain plant communities from the Taurus range (Döring 2001; Hein et al. 1998; Kürschner 1982; Kürschner et al. 1998; Parolly 1995, 1998, 2004; Tolimir 2001).

A strong orographic isolation and the absence of larger ice-shields during the ice-ages appear to be crucial for the present high-mountain endemism in many SW Asian- and Mediterranean-type mountain ranges (Noroozi et al. 2011).

By contrast, the widespread and often hygrophytic other vegetation classes harbor no or extremely few endemics as exemplified in the meadows of the Molinio-Arrhenatheretea and the bryophyte-rich vegetation along springs and edges of rapids classified within the Montio-Cardaminetea (both 0 %) or the low-sedge fens of the Scheuchzerio-Caricetea fuscae (3.7 %). The local development of *Kobresia humilis* turf has at least 16.6 % of endemic species. At such places widely distributed Irano-Turanian elements such as *Cirsium rhizocephalum, Gentianella holosteoides, Inula acaulis* (Fig. 3.3f), *Kobresia humilis, Primula auriculata, Swertia longifolia* (Fig. 3.3g), *Taraxacum crepidiforme, Veronica biloba* and *V. pusilla* and wide-Euro-

Siberian or narrower Euxine-Caucasian elements such as *Gentiana verna* subsp. *pontica* and *Pinguicula vulgaris* subsp. *balcana* can gain dominance.

Distribution of Endemic SPAC Among the Altitudinal Groups A chorological analysis (Fig. 3.5) of the altitudinal groups—L, M, A, A+S and P−, reveals the rising proportions of the Irano-Anatolian element with increasing altitude (L: 8.7 to A+S: 24.1 %) and, vice versa, the lowered proportion of the E Mediterranean element s.l. from 17.4 in group L (18 % in M) to poor 3.8 % in high alpine-subnival elevations (group A+S). The same altitudinal trend is obvious within the endemics (rising from 43.5 % in L to 54.4 % in A+S) and local endemics (none to 13.9 %). Endemism rates increasing with altitude were also reported from the mountains of Iran, from Mediterranean-type mountains (e.g., Sierra Nevada and Apennines) and some mountain ranges subjected to temperate climate such as the NE Calcareous Alps or the central Caucasus (Erschbamer et al. 2010; Nakhutrishvili 1996; Noroozi et al. 2011; Pauli et al. 2011).

While the groups L, A, and A+S comprise taxa, which reach their upper distributional limits in the subalpine, alpine and subnival belts, respectively (and are often centered there), taxa of the group M spread over wide altitudinal amplitudes.

Group P stands apart from the general trend in displaying the highest percentage of endemics (84.9 % in total) within vegetation units developed on summits too low to reach the alpine life zone sensu Körner (2003). This pseudo-alpine group features 26.4 % of local endemics and 49.1 % of endemics occurring in a larger portion of the Taurus Mts. (endemics of the Batı or Orta Toroslar).

A narrow vertical distribution restricted to high altitudes often corresponds to constricted geographic range. Vice versa, species with wider amplitude of their altitudinal distribution commonly are widespread species (Noroozi et al. 2011). The present results underpin this trend impressively and clearly show how vulnerable the endemic-rich flora of the Taurus Mts. really is.

3.6 Concluding Remarks

Outlook The predicted climate warming and impact on the hydrologic situation may seriously threaten the survival of the unique cryophilic and hygrophilic high-mountain flora of the Western and Central Taurus. The narrower the altitudinal distribution, the geographical range, and the genetic diversity and plasticity within a species, the more severe is the potential vulnerability to climate change (Noroozi et al. 2011). This particularly accounts for the endemic species of group A, A+S, and P, and to a lesser extent, for the hygrophilic flora of the Taurus range.

The expected upward migration of taxa may lead to a full upward shift of whole vegetation belts in combination with a stepwise aridization. In this case, additional pressure through drought-tolerant competitors from lower altitudes can further increase the risk of biodiversity losses (Noroozi et al. 2011). The invasion of xero-tolerant species from lower elevations is furthered by the degradation of the once existing migration barriers such as closed forests. Instead, already now there are many bare mountains and slopes, those open habitats are occupied by zonal Astragalo-Brometea grasslands and dwarf-shrub communities, expanding from the lower elevations up to the highest summits. This situation is a feature of Mediterranean- and SW Asian-type high mountain ranges and expected to support an upward colonization driven by climate change (Noroozi et al. 2011; Pauli et al. 2011, and references therein).

With an upward shift of life zones, the anthropogeneous impact may even reach higher up in the future. Driven by shrinking grazing grounds and water resources and longer snow-free seasons, grazing by sheep and goats may increase once more. Overgrazing is presently and since a long time among the most severe threats for conserving the diversity of open habitats in Turkey (e.g., Kürschner and Parolly 2012; Özhatay et al. 2003). Uncontrolled construction activities and, at a local scale, the expansion of skiing resorts, further harm the high-mountain flora and vegetation (Eren et al. 2004).

Upward shifts and migrations of populations, individuals and plant communities will affect the distribution areas of taxa (shrinkage, losses and expansion of horizontal and vertical ranges), their phenology, complex interactions (e.g., competition, pollination, phytopathogenes) with the environment and the genetic structure of their populations (e.g., Essl and Rabitsch 2013). Species and plant communities are equally affected.

Shifts in land-use systems may additionally contribute much to the loss of biodiversity both in species and plant communities. In 1999 and 2000, the author had the opportunity to revisit the Geyik Dağları after a first trip in 1992. The plateau between the Büyük Geyik Dağı and the Akdağ was dotted by glacial lakes and karstic pools, supporting a diverse hygrophytic plant life (Raab-Straube 1994) as well as a yayla (summer pasture). Only a few years later, this yayla was, following road constructions, replaced by a permanent settlement—with dramatic impacts on the whole high-mountain environment. The massive lowering of the water table of the plateau turned the shallow lakes once full of life into muddy flats, while the grazing by an enhanced and now permanently present livestock severely has degraded even the vegetation of the alpine belt.

Summarizing Conclusions Evaluating phytosociological relevés is, with some reservations, a quick and powerful approach to identify plants within their life zones (altitudinal and site-ecological groups) and to predict future climate change-triggered reactions by interpreting their site-ecology and distribution patterns. Methodical limitations are given by the necessarily incomplete geographical sampling (the relevés come from a selection of mountain areas only), selective vegetation sampling (not all units are documented by a suitable number of relevés) and by the sampling protocol of the Braun-Blanquet approach (1964), where both an ecological and floristic homogeneity of the plots is mandatory. Hence, plants growing at transitional sites will normally not enter such studies. Consequently, the present list (Appendix) has to be completed by the evaluation of the Flora of Turkey (Davis 1965–1985; Davis et al. 1988; Güner et al. 2000), the many local florae and herbarium studies.

In the Western and Central Taurus, 336 vascular plant species were identified to be potentially affected by climate warming ("prewarn list"). The 180 cryophilic plant taxa included in the altitudinal groups A, A+S, and P, appear to be vulnerable due to the limited options to migrate to alternative low-temperature habitats at higher elevations. The dispersal strategies of the high-mountain taxa are diverse, but mostly allow short-range dispersal only (Parolly 1995, 2004 and unpublished data), thus lowering the chance to reach other suitable habitats at more remote summits.

The outstanding level of high-altitude endemism, resulting mainly from orographic isolation of the highly scattered and fragmented cold areas and the absence of extensive Pleistocene glaciations (Noroozi et al. 2011; Parolly et al. 2010; Pauli et al. 2011), ought to be particularly threatened by the scenarios of climate warming.

It is important to note that global warming will also affect whole plant communities; 75 putative candidate communities were identified in the present chapter.

In order to follow the expected changes and to provide scenarios for future vegetation development, it is crucial to start monitoring the changes of the plant diversity in long-term plots along the altitudinal gradients of the mountain ecosystems. Such studies should be supplemented by phenological observations.

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Chapter 4
Soil Carbon Reservoirs at High-Altitude Ecosystems in the Andean Plateau

M. A. Munoz, Angel Faz and Ahmet R. Mermut

4.1 Introduction

4.1.1 Mountain Ecosystem Coverage

Mountains and uplands represent the world's most diverse and fragile ecosystems, cover about 20% of the terrestrial surface, and are distributed across all continents and major ecoregions (Heywood et al. 1994). While about 10% of the world's population lives in these environments, mountains provide important economic resources. Mountain ecosystems are rich sources of biodiversity and provide ecosystem services for their inhabitants (Brooks et al. 2006). These regions are currently threatened by land use and land cover changes, therefore an efficient monitoring is required to capture such changes (Tovar et al. 2013). Mountain environments support human communities, ecological landscapes, and organisms which are strongly influenced by temperature and precipitation changes. For this reason, they are good indicators of the impacts of the climate change.

The Andean plateau is the main mountain range of the American continent and one of the largest in the world, measuring more than 7500 km. The high-elevation habitats of the South American Andes extend from 11°N to 56°S (Arroyo and Cavieres 2013) and involve Argentina, Chile, Bolivia, Peru, Ecuador, Colombia, and Venezuela. Global human and biodiversity responses to climate change cannot be understood without an understanding of carbon (C) dynamics and reservoirs in the Andean region (Coûteaux et al. 2002).

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4.1.2 Soil Organic Carbon

In the past two decades, a number of studies on soil C have been conducted across different grassland types around the world (Wang and Fang 2009). These studies make it possible to analyze soil C stocks in the Andean plateau. The soil organic matter (SOM) is a cornerstone pool in the fertility management of the Andean agriculture as well as the control of erosion. Mountain soils are considered to be a large regional soil C reservoir in the global cycling. The mountain soils are headwater areas of catchments controlling densely populated valleys justified to improve our knowledge concerns to soil C reservoirs in the Andean region (Bottner et al. 2006).

The global C cycle depends mainly on the SOM dynamics (Lal 2001) and the Kyoto Protocol includes the soil C reserves in the grasslands for the reduction of green house effects (Kenneth et al. 2007). Growing interest in the potential for soils to provide a sink for atmospheric C has prompted studies of effects of management on the amount and nature of soil organic C (SOC; Ganjegunte et al. 2005). SOC reserves are the result of the balance between organic carbon (OC) inputs and the mineralization average of each SOM groups (Post and Kwon 2000).

In order to understand SOM dynamics, it is fundamental not only to quantify the OC contents but also to know the processes which provide nutrients to plants. In this sense, OC and organic nitrogen contents are essential to determine the soil C reservoirs while C/N ratio helps to determine the rate of C mineralization (Brady and Weil 2008) as well as soil respiration (Högberg and Read 2006). Moreover, it is crucial to gain knowledge about the different C pools and functional groups in order to establish the rate of SOM biodegradation (Preston et al. 1987; Stevenson 1994). Likewise, SOC is the most labile and reactive SOM fraction and it determines the C stability in the soil (Zhao et al. 2008). On the other hand, the recalcitrant C (RC) fraction provides information about the long-term C storage (Belay-Tedla et al. 2009).

4.1.3 C Reservoirs at High-Altitude Grasslands

The influence of current global climatic change on SOC reservoirs and dynamics is still not clearly understood in high-altitude grasslands (Davidson and Janssens 2006; Xu et al. 2010). Authors such as García-Pausas et al. (2008) suggested that the C stabilization mechanisms in mountain grassland soils may be affected by the climate. Zehetner and Miller (2006) assessed a slow SOM decomposition due to the lower temperatures and soil pH in the Andean agroecosystems. Many studies have focused on short-term dynamics, but there is recent evidence that the dominant slow pools of SOM are more sensitive to temperature than the fast pools. This fact implies stronger long-term responses than previously anticipated (Knorr et al. 2005).

Due to the lack of specialized surveys conducted in the Andean plateau and in order to provide essential information about this hotspot in the soil C study, further researches should be carried out in ecosystems such as the Andean high-altitude grasslands. These singular habitats have been very poorly understood and the present altitudinal patterns are likely to be altered by future climate change in the Andean region (Zehetner and Miller 2006). The study of soil C reservoirs and the implication of the SOM in the fertility management, the erosion control, the conservation of biodiversity, and the global climate change justified to improve its knowledge on the Andean plateau (Bottner et al. 2006).

4.2 Climate Data in Andean Grasslands

In general, the Andean climate is affected by three main factors: ocean currents, winds, and orography. Rainfall tends to increase with elevation. Moisture reaches the mountains primarily from the east, but rainfall in some inter-Andean valleys and on the western flank of the cordillera is also influenced by weather originating in the Pacific (Harden 2006). The entire Andean belt is segmented into the northern, central, and southern Andes (Decou et al. 2011). There are noticeable changes in the northern Andes climate compared to that in the central and south Andes.

The northern Andes of Venezuela, Colombia, and Ecuador is called paramo and its altitude ranges between 3300 and 4800 m.a.s.l. The paramo is characterized by humid climate with 800–1300 mm of mean precipitation falling annually, mostly as rainfall during the wet season that extends from May to November (Coûteaux et al. 2002; Bottner et al. 2006). The mean annual temperature ranges from 5 to 10 °C. There is a little seasonal fluctuation in temperature (between 7 and 12 °C) and a 15–20 °C diurnal fluctuation is normally experienced (Medina and Turcotte 1999; Harden 2006; Bottner et al. 2006). Diurnal variation is more pronounced in the dry season due to reduced cloud cover (Mahaney et al. 2007). Climate in northern Peru is classified as tropical summer rain high mountain climate (Haw) according to Koppen's reformed classification (Rudloff 1981; Baigorria and Romero 2007).

In contrast, the climate of the central and the south Andes which groups southern Peru, Bolivia, Chile, and Argentina is further characterized by an expressed seasonality with a dry season of pronounced water deficit from June to September. About 85 % of the annual precipitation occurs from November to March (Moreau et al. 2003). The altitude ranges from 3800 to 5100 m.a.s.l. and this ecosystem is called puna. The mean annual precipitation could range from 350 to 700 mm and the mean temperature ranges from 5 to 10 °C (Bottner et al. 2006; Muñoz and Faz 2012). A high daily thermal amplitude (from 25 to 0 °C) due to intense solar radiation and low water vapor content in the atmosphere at such high altitude (Moreau et al. 2003) with low seasonal thermal variations (differences of 8–10 °C between summer and winter) has been reported.

4.3 Geomorphology, Hydrology, Geology, and Edaphology

4.3.1 Geomorphology and Hydrology

Because the Andes are still tectonically active (Norabuena et al. 1998), the physical setting includes active volcanism, ongoing uplift, earthquakes, and high magnitude mass movements. Uplift has caused rivers to incise (Safran et al. 2005) and denudation rates to be high (Aalto et al. 2006; Harden 2006). The highest peaks reach to nearly 7000 m.a.s.l. and are snow-capped. On the Atlantic and Pacific sides, relief is dramatic and hill slopes and river gradients are steep. Most of the region is tectonically active, and sections of it are volcanically active (Harden 2006). The Andes are characterized by an abrupt topography which ranges from 5500 m.a.s.l. to drop to less than 100 m into the tropical Amazon basin (Ecuador, Peru, and Bolivia). The distance traversed in the narrowest distance is approximately 200 km in the Ecuadorian Andes, while across the Altiplano of Peru and Bolivia, the distance is 500 km.

Due to tectonic processes over millions of years, an unstable landscape has been created which is unsurpassed in variety and complexity (Bottner et al. 2006). The cordilleras of the Andes divide the Pacific from Atlantic drainages and capture and regulate the flow of water for most of the South America continent. On the Atlantic side, the Amazon River basin comprises 34 % of the land area of South America. Other major drainage basins are the Orinoco (Atlantic), Magdalena (Caribbean), and Paraná (Atlantic).

The hydrological resources of the Andes are virtually unique in the world in that they can be harnessed along most parts of their rapid 4000–5000 m descent (Coûteaux et al. 2002). Traversing both the Pacific and Amazonia slopes of the Andes are dozens of major river systems which ecologically link the highlands and the lowlands. Westward-flowing rivers from southern Ecuador to central Chile deliver water to arid lands as they flow from mountain to ocean. The Magdalena River basin of Colombia has generally received less rain in El Niño years and more in the La Niña years (Restrepo and Kjerfve 2000). Similarly, pulses of deposition from Andean headwaters, recorded in floodplain sediment cores in the Beni and Mamore river basins, two Bolivian tributaries of the Amazon, were associated with La Niña events (Aalto et al. 2003; Harden 2006).

4.3.2 Geology

According to Mahaney et al. (2007), the northern Venezuelan Andes exhibits a general near-uniform lithology/parent materials. They present terraces formed in large part due to stream incision/migration triggered by Neotectonic uplift of a Late Glacial/Early Holocene glaciolacustrine lithosequence. Bedrock in the study area is dominantly granite and gneiss (Kunding 1938; Mahaney and Kalm 1996). Terrace surfaces are relatively flat or gently sloping toward the modern stream channel and generally well drained. Exceptionally, the current floodplain and areas designated as “wet slope” which are prone to saturation in some cases due to seepage can be found. Lithology is relatively uniform within deposits of the lower terraces. It includes nearly identical suites of both light and heavy minerals that reflect the local metamorphic bedrock (Mahaney and Kalm 1996). The highest terraces contain elevated concentrations of heavy minerals that appear as distinctive black sand concentrations.

4.3.3 Soils

Soils formed on volcanic deposits such as Andean mountain range have the reputation of being fertile and highly productive (Buytaert et al. 2006). However, the properties of these soils undergo dramatic changes in the course of pedological development. The importance of climatic conditions on the colloidal composition of volcanic ash soils has been recognized in several surveys (Parfitt et al. 1983; Nieuwenhuyse et al. 2000; Zehetner and Miller 2006).

At high elevations, the soil’s clay mineralogy is dominated by active amorphous constituents (Zehetner et al. 2003; Zehetner and Miller 2006) and is a typical weathering product in volcanic ash soils. They require humid conditions for their formation (Parfitt et al. 1983; Parfitt et al. 1984). Active amorphous materials, such as allophane and aluminum–humus complexes, dominate the clay fraction where the climate is moist and soil solution silicon is removed by leaching. Halloysite is found as the dominant clay mineral in drier silicon-rich environments. Such mineralogical differences have important bearings on the biogeochemical cycling in the ecosystems of volcanic landscapes. Active amorphous materials are known for their strong sorption of phosphate and for their stabilizing effects on SOM (Parfitt et al. 1984; Shoji et al. 1993; Zehetner and Miller 2006). Moreover, the acidity induces a high content of exchangeable aluminum and free Al (Bottner et al. 2006).

Paramo soils, in Ecuador, Colombia, and Venezuela, consist of a very black, highly organic epipedon (A, Ah, and/or O horizons) discontinuously overlying an unrelated inorganic surface (Podwojewski and Poulenard 2000; Otero et al. 2011). Because mineral particles in paramo soils are eolian in origin, paramo soils near to and downwind from active volcanoes may be 1–2 m thick, while soils farther from ash sources or on glaciated surfaces may be only 20–30-cm in depth (Harden 2006). The most common soils in the páramo are Andisols, Entisols, Inceptisols, and Histosols according to the soil taxonomy (Soil Survey Staff 2010) classification, or Andosols, Regosols, Umbrisols, and Histosols in Food and Agriculture Organization’s (FAO) World Reference Base for Soil Resources (FAO-ISRIC-ISSS 2006) (Coûteaux et al. 2002; Buytaert et al. 2006; Bottner et al. 2006; Harden 2006). In the southern Andes region of Ecuador, Dercon et al. (2007) observed humic Umbrisols Andosols at 3000 m.a.s.l.

Andosols have appreciable amounts of weatherable primary minerals and pyroclastic glass (data not shown), and comparatively low clay contents, which reflect their young age (Zehetner et al. 2003). Andosols, located at high elevation where higher rainfall and lower evapotranspiration result have greater leaching and less-pronounced seasonal drying. This has favored the formation of active amorphous materials, such as allophane, in the upper profile, which in turn has profound effects on the soil's physicochemical behavior. Active amorphous materials may also have contributed to the stabilization and accumulation of SOM in the upper horizons of the Andosols (Zehetner and Miller 2006). Andic soil properties increase with elevation and according to US soil taxonomy (Soil Survey Staff 2010). The high-elevation soils are classified as Andosols and the low-elevation soils as Inceptisols and Entisols (Zehetner et al. 2003). In more water-saturated areas or regions with less volcanic influence, organic soils such as Histosols have been found (Buytaert et al. 2006).

Northern Andean highlands of Peru were classified by Baigorria and Romero (2007) as Entisols, Inceptisols, and Mollisols according to Soil Survey Staff (2010). Entisols are usually located at lower elevation where lower rainfall and higher evapotranspiration cause less leaching and the soils experience a pronounced period of desiccation during the dry season. As a result, active amorphous materials are absent and the colloidal fraction is dominated by the less reactive clay mineral halloysite (Zehetner and Miller 2006).

Bottener et al. (2006) found Haplic Xerosol in the southern Bolivian puna. The soil was shallow, sandy, stony with very low organic matter (OM) and the exchangeable and free Al contents were negligible. On the other hand, Muñoz and Faz (2012) identified Entisols and Inceptisols Soil Survey Staff (2010) and Cambisols, Regosols, Umbrisols, and Phaeozems according to FAO's classification (FAO-ISRIC-ISSS 2006) in the northern Bolivian puna.

4.4 Soil Characteristics: C, C/N ratio, Water-Soluble OC, RC, Functional Groups, Soil Respiration, and Soil Mineralization

Two main factors determine the Andean soil type and properties: (1) the climate and (2) the existence of a homogeneous layer of volcanic ashes from quaternary volcanic eruptions (Barberi et al. 1988 and Winckell et al. 1991). The cold and wet climate and the low atmospheric pressure favor OM accumulation in the soil (Medina and Turcotte 1999; Harden 2006).

This accumulation is further enhanced by the formation of organometallic complexes strongly resisting to the microbial breakdown. Aluminum and iron in these complexes are supplied by the breakdown of volcanic ashes and bedrock (Nanzyo et al. 1993; Buytaert et al. 2006). Accordingly, the large sequestration of OM generally observed in the paramo soils can be explained by two abiotic factors: the unfavorable soil microstructure and the accumulation of free aluminum linked to the climatic and acid soil conditions, inhibiting the microbial activity physically and chemically (Bottner et al. 2006).

4.4.1 Soil OC

Zehetner and Miller (2006) studied some soil properties in Ecuadorian Andean soils and observed an OM content increase with the altitude, likely a result of slowed decomposition due to lower temperatures and lower soil pH at higher elevations. The presence of active amorphous materials may further have contributed to this accumulation by protecting OM against microbial decomposition and prevent the soil erosion. The stabilizing effects of active amorphous materials on SOM have been demonstrated by Parfitt et al. (1997) and Zehetner and Miller (2006). These authors reported decreases of OM contents upon conversion from pasture to cropland that were considerably higher in an Inceptisol than in an Andosol which contained active amorphous materials. Several authors found that around 40–60 % of the SOC exist within the top 20-cm layer in high grasslands (Jobbàgy and Jackson 2000), Pyrenean mountain grasslands (García-Pausas et al. 2008), and Andean grasslands (Muñoz and Faz 2012).

Otero et al. (2011) found high concentrations of OC (6.2 %) in the Andean paramo of Colombia similar to those observed by Zehetner and Miller (2006) in the Ecuadorian paramo. Coûteaux et al. (2002) observed 4.6 % of OC in Entisols located in Andean Venezuelan paramo, while Bottner et al. (2006) found higher C contents (9.9 %) similar to those contents found by Abadín et al. (2002) in the Venezuela highlands which ranged from 7.1 to 8.4 %. Furthermore, Harden (2006) described the typical content of OM in Histosols located in the paramo to be around 30 %. The paramo soils contain up to 45 kg OC m^{-2} distributed over 50-cm depth.

Under the moist conditions of paramo, the soil carbon content is up to 10 % and SOM seems to be the main factor determining the soil physical properties and erosion sensitivity (Poulenard et al. 2003; Bottner et al. 2006). They contain elevated amounts of OC which is typically around 100 g kg^{-1}. In wet locations (> 900 mm yr^{-1}), OC contents of up to more than 40 % are not uncommon (Buytaert et al. 2005). Locations with more frequent ash deposits are characterized by younger soils with a C content of about 4–10 % (Zehetner et al. 2003). In dryer regions, OM accumulation could be lower, although C contents (7 % of OC) were found by Podwojewski et al. (2002) in the paramo with < 600 mm yr^{-1} of rainfall.

According to Bottner et al. (2006), under the drier conditions of the puna, the C contents were less than 1 %. However, high total OC (TOC) contents were observed by Muñoz and Faz (2012) with 9.1 kg C m^{-2} between 0 and 5-cm depth and 13.4 kg C m^{-2} between 5 and 15-cm depth in the northern Bolivian puna (500 mm $year^{-1}$). These OC contents are higher than those found by some authors (3.0 kg C m^{-2}) in high-altitude grasslands located in the Tibet plateau at 0–10-cm depth (4100–5100 m.a.s.l; Genxu et al. 2008), while Wu et al. (2003) observed 10–12 kg C m^{-2} in the Quinhay–Tibet plateau from 0 to 30-cm depth. Ganjegunte et al. (2005) studied the C reservoirs in northern High Plains grasslands in USA where the SOC contents were significantly greater in light grazing grasslands (13.8 mg ha^{-1}) than in heavy grazing or nongrazed ones with similar results to those found in the northern Bolivian puna.

The much higher SOM content in paramo, despite more favorable climatic decomposition conditions, cannot entirely be explained by the difference in plant biomass and residues production between paramo and puna (Bottner et al. 2006). The external climatic conditions acting specifically on ecosystem productivity and decomposition are often not sufficient to explain the accumulation of SOM. Schimel and Weintraub (2003) highlighted the role of the labile plant material among the classical biotic factors defining the quality of the plant residues (nutrient content and availability, C/N ratio, lignin content, N/lignin ratio, etc.). The labile plant material provides microorganisms with energy for exoenzyme activity allowing the decomposition of recalcitrant material (Bottner et al. 2006).

4.4.2 C/N ratio

High C/N ratio described by Abadín et al. (2002) and Coûteaux et al. (2002) in two different researches conducted in the Andean Venezuelan highlands (18.2 and 16.2, respectively) could indicate that humification would be more intense than mineralization processes. These values were similar to those assessed by Bottner et al. (2006) in Venezuelan highlands (C/N ratio 15.3) in front of the C/N ratio found in the southern Bolivian puna (7.6). However, Muñoz and Faz (2012) described the C/N ratio ranging from 11.3 to 14.3 in the northern Bolivian puna, lower than those found by Coûteaux et al. (2002) in the Venezuelan paramo and higher than the C/N ratio observed by Bottner et al. (2006) in the southern Bolivian puna.

The paramo soils could exhibit a general predominance of humification processes compared to the puna soils which could show a more equilibrated relationship between mineralization and humification processes. This difference could be explained based on the different climatological conditions, particularly, the plentiful rainfall in the paramo that triggers the higher soil moisture coupled with the formation of organometallic complexes resistant to the microbial decomposition.

4.4.3 Water-Soluble OC

Water soluble OC (WSOC) serves as substrate for microbial biomass turnover and it is identified as labile C with fast decomposition or fast mineralization rate (Zhao et al. 2008). Due to the lack of data from the researchers carried out in the Andean region about this parameter, we show merely data from one study conducted in the Bolivian puna that are compared with others from highlands around the world. This comparison will be presented again for other parameters such as RC, functional groups, and soil respiration.

The highest WSOC values found in the northern Bolivian puna were 671.1 mg WSOC kg^{-1} (0–5-cm depth at surface) and 579.7 mg WSOC kg^{-1} (5–15-cm depth at subsurface). On the contrary, the lowest WSOC contents were 249.2 and 223.8 mg WSOC kg^{-1}, at surface and subsurface, respectively (Muñoz and Faz 2012). These

WSOC contents were within the range described by Halvorson and González (2008) in grasslands (500–2000 mg WSOC kg^{-1}), while all subsurface WSOC contents were above these authors' range (200–600 mg WSOC kg^{-1}). According to Zhao et al. (2008), there is a positive relationship between WSOC fraction and mineralization processes. Based on WSOC/TOC ratio, Muñoz and Faz (2012) observed that mineralization processes would be a bit more intensive at 5–15-cm depth although the C/N ratio observed in the northern Bolivian puna did not show a clear predominance of the mineralization processes compared to the humification ones.

4.4.4 Recalcitrant C

Chemical fractionation of SOM into various C pools using acid hydrolysis procedure allows one to study labile pool of small molecular size characterized by rapid turnover and a large molecular weight RC fraction of slow turnover (McLauchlan and Hobbie 2004). Stable compounds of SOM include fossil or black carbon which plays many important roles in the global C storage (Kögel-Knabner et al. 2008). In terms of stability, recalcitrance can be defined as the ability to resist abiotic and/or biotic degradation (Harvey et al. 2012).

According to the survey carried out by Muñoz et al. (2013) in the northern Bolivian puna, the highest RC contents were 3.7 kg RC m^{-2} at 0–5-cm depth and 1.7 kg RC m^{-2} at 5–15-cm depth. The recalcitrant index (RC/TOC ratio) observed ranged between 70 and 80 %. Cheng et al. (2007) found RC contents around 2.2 g RC kg^{-1} in agroecosystems in the USA (0–15-cm depth) and a recalcitrant index around 41 %. Rovira and Vallejo (2007) observed a recalcitrant index of 53 % in the surface horizon of Mediterranean forest soils. The very high recalcitrant index found in the northern Bolivian puna suggests a high storage of RC. High storage of RC is advantageous to the preservation or stabilization of soil mineral particles and the long-term C sequestration (Belay-Tedla et al. 2009; Rovira and Vallejo 2007). Authors such as García-Pausas et al. (2008) suggested that the C stabilization mechanisms in mountain grassland soils may be affected by the climate, particularly by the low temperature. Knorr et al. (2005) established that higher temperature may stimulate decomposition of the recalcitrant pools. Taking into account these arguments and the high RC contents found, the northern Bolivian puna could contain very valuable stable C reservoirs likely due to the low temperature and the high plant cover (Muñoz and Faz 2009). The OM deposition from the vegetation would increase the C contents and the low temperature would decrease the RC decomposition enhancing the stable C stocks. However, the increase of the temperature due to the global change could seriously affect these essential C reservoirs.

Davidson and Janssens (2006) stated the lack of consensus on the temperature sensitivity of soil C decomposition as this effect is particularly difficult to establish due to diversity of soil organic compounds and their variable kinetic properties. However, there is recent report that the dominant slow decomposing pools of SOM are more sensitive to temperature changes than the fast pools (Zehetner and Miller 2006). Therefore, the temperature increases associated with the global climatic change could promote more CO_2 releases from RC in some zones at the Andean plateau, similar to the findings described by Xu et al. (2010) in the cold Chinese region.

4.4.5 Functional Groups

Carbon functional groups have usually been studied by the nuclear magnetic resonance technique (NMR) ^{13}C CP/MAS-NMR in order to characterize SOM quality and composition. Particularly, NMR analyses worked efficiently in the identification of the distribution of various types of C during decomposition and humification of SOM (Oades et al. 1987; Preston et al. 1994; Dignac et al. 2002). Authors such as Lorenz et al. (2006) and Mahieu et al. (1999) establish that the general composition of the SOM would be O-alkyl-C (45 %), alkyl-C (25 %), aromatic-C (20 %), and carboxyl-C (10 %). Accordingly, Muñoz and Faz (2012) observed higher alkyl-C percentages in the northern Bolivian puna ranging from 33 to 43 % in comparison with those observed by other authors who established 20–25 % of alkyl-C (Faz et al. 2002; Kavdir et al. 2005; Leifeld and Kögel-Knabner 2005). Moreover, the high O-alkyl subgroup signal (60–98 ppm) observed in the northern Bolivian puna indicated undecomposed plant litter based on other survey results (Kavdir et al. 2005).

According to TOC/O–alkyl-C positive correlation found in the northern Bolivian puna, it can be established that more TOC involves a high quantity of undecomposed plant litter and a highest potential for decomposition (Kavdir et al. 2005). In general, the alkyl-C/O–alkyl-C ratio (above 0.7) could indicate certain relevance of humification (Dignac et al. 2002) likely due to the singular climate conditions, although this predominance would not be very relevant based on C/N ratio which indicated equilibrium between humification and mineralization processes (Muñoz and Faz 2012).

4.4.6 Soil Respiration and Soil Mineralization

Soil respiration is the primary pathway for CO_2 fixed by plants returning to the atmosphere (Högberg and Read 2006: Wang and Fang 2009). Soil respiration in grasslands consists mainly of respiration from roots and associated mycorrhizal fungi and microbial respiration. The basal respiration rate is the parameter that most promptly responds to soil disturbance (Hungria et al. 2009). Particularly, soil biological properties seem to have a greater potential than chemical or physical properties to indicate soil fertility in this mountain heterogeneous context because they are more sensitive to land-use changes (Sarmiento and Bottner 2002). It is extremely important to know the CO_2 fluxes and its implications to the global increase of CO_2 levels in the atmosphere to add knowledge about the relevance of long-term C stocks in the Andean plateau.

Muñoz et al. (2013) determined the soil respiration rate at 15 °C (the maximum temperature in the northern Bolivian puna) and at 25 °C (the standard temperature to determine the soil respiration rate). They observed the highest CO_2 efflux at 25 °C (2786.9 g CO_2 m^{-2} yr^{-1}) at 0–5-cm depth while the highest soil respiration observed at 15 °C was above 1000 g CO_2 m^{-2} yr^{-1} at 5–15-cm depth. The annual soil CO_2 efflux was estimated to be 400 g CO_2 m^{-2} yr^{-1} for temperate grasslands in the north-east of China (Wang and Fang 2009) and around 200 g CO_2 m^{-2} yr^{-1} in semiarid steppes in inner Mongolia (Zhang et al. 2003). Hence, we can establish that the northern Bolivian puna could have a higher potentially mineralizable C at 15 °C than other temperate highlands in the world based on the soil respiration rate. The ratio between soil respiration at 15 and 25 °C (Q_{10}) showed that the temperature increase could impose a negative impact mainly in subsurface (5–15-cm depth) where the microorganisms would be rapidly activated in the northern Bolivian puna (Muñoz et al. 2013).

The soil mineralization in the paramo was studied by Martin and Haider (1986), Carballas et al. (1978), and Miltner and Zech (1998) who observed a slower decomposition of the bulk OM and of specific compounds such as sugars, polysaccharides, or phenols in the presence of ferrihydrites and Al hydroxides. The inhibition of decomposition was ascribed to chemical stabilization processes by organo-mineral bounding, to the insolubilization of the organic compounds, and/or to the toxicity effect of Al hydroxides for microorganisms (Bottner et al. 2006).

Coûteaux et al. (2002) assessed the SOM protection based on stable organo-aluminum complexes in Andean Venezuelan highlands. In addition, Abadín et al. (2002) suggested that the high soil contents of exchangeable Al^{3+} and free Al oxides point out that Al plays an important role in SOM stabilization, lowering its mineralization in the Venezuelan northern Andes. The abundance of acidity-generating ions (H^+ and Al^{3+}) that widely dominate the soil complex of exchangeable cations also may favor the soil acidification processes because an important fraction of these ions is easily displaced from the cation-exchange capacity (CEC) to the soil solution (Abadín et al. 2002). Therefore, aluminum likely plays in these soils an important role in the OM dynamics, lowering its mineralization. Global climate models predict a warming of 1–3 °C in the region by 2050 (Zehetner and Miller 2006). However, regional precipitation scenarios vary greatly among different simulation models, especially for the highland areas; some models predict decreasing, others increasing, rainfall. The projected temperature increase will certainly accelerate OM decomposition, particularly where OM is not protected by active amorphous materials, as it seems to be in the central Bolivian Andes (Zehetner and Miller 2006; Bottner et al. 2006).

4.5 Biomass Production: Plant Cover, More Relevant Species Height, Weight of Biomass

Highest species richness has been found in the paramo, followed by the puna and the southern Andean steppe (Arroyo and Cavieres 2013). These geologically young habitats bear a rich vascular flora, which can be accompanied by abundant mosses, lichens, and hepatics in the paramo. In the vast semiarid Andean highland areas of the Andean plateau where vegetation productivity is relatively low, native wetland forage grasses represent a key resource for the livestock production. The native wetland forages are mainly *totorales* (lake-shoreline rushes) and *bofedales* (heterogeneous, short and dense grasslands, crisscrossed by shallow streamlets), present in the Andean region from Venezuela to Chile (Moreau et al. 2003). In the Andean wet grasslands, the continued growth and somewhat low senescence during the Austral dry winter with small variations of plant cover has been observed (Buttolph 1998). This fact is explained by the permanent availability of water in soils (Moreau et al. 2003).

In general, Andean vegetation shows numerous adaptations to high UV radiation and the moisture stress caused by low temperatures, high rates of transpiration during sunny periods, and desiccating winds. Many plants are evergreens, have sclerophyllous leaves, or have leaves that are gray-hued to maximize UV reflectivity. "Rosette habit" and tussock-forming grasses are common, as these adaptations create a warmer and wetter microclimate around the plant (Perez 1996; Luteyn 1999). It is also common to find mosses acting as substrates for other plants, because mosses retain moisture better than some soils present (Perez 1992; Mahaney et al. 2007). Regarding the botanical identification, the dominance of perennial species could indicate better adaptation of them to the extreme climate conditions in the Andean region (English et al. 2005; Muñoz and Faz 2014).

A qualitative study of plant functional types conducted by Mahaney et al. (2007) across the terrace sequence in the Venezuelan Andes showed that older surfaces supported greater plant diversity. The paramo is characterized by high biological diversity and endemism (Schubert and Vivas 1993; Luteyn 1999). Paramo vegetation varies, but is most commonly grass (*Calamagrostis* sp., *Stipa* sp., and *Agrostis* sp.), with some shrubs in less disturbed sites (Harden 2006). Other authors such as Coûteaux et al. (2002) found that a general vegetation of giant rosettes of *Espeletia schultzii* and shrubs of *Hypericum laricoides* dominate the vegetation in the Andean Venezuelan highlands. Among the flowering plants, there is a preponderance of mainly temperate families (Apiaceae, Geraniaceae, Polygonaceae, Rosaceae). Dominant plant vascular genera are: *Acaena, Aciachne, Carex bonplandii, Espeletia, Hypericum, Niphogeton, Sisyrinchium* (Mahaney et al. 2007).

The northern Bolivian puna vegetation has been identified by altoandine and puna vegetation units according to Beck et al. (2003). Muñoz and Faz (2014) identified *Aciachne, Festuca, Deyeuxia, Stipa, Pycnophyllum, Tarasa*, *Azorella,* and *Lachemilla* as predominant in the northern Bolivian puna. Moreover, they identified *Plantago, Scirpus,* or *Luzula* in the wet zones.

Shen et al. (2011) established that the water availability is one of the critical environmental factors that regulate vegetation activities in many areas such as arid and semiarid grasslands (Ji and Peters 2003; Pennington and Collins 2007). Pangtey et al. (1990) assessed that soil water availability is essential for growth initiation of some species at the alpine grasslands in the Central Himalaya. Although a seasonality influence could be assessed for some plant species in the northern Bolivian puna, in general a predominant growing during the wet season which could depend on each species could not be established (Muñoz and Faz 2014).

Soil N is usually the other limiting factor in herbaceous biomass production in semiarid and arid grasslands as emphasized by Dregne (1998) and Xuelin et al. (2008). Animals have to cover large distances to graze in semiarid grasslands and the N excreted by animals can have a long distribution out of the root influence zone, breaking down the return rate of this element to the plant (Burke et al. 1998). Related to the grazing, disturbed vegetation was observed in the Andean northern Bolivian grasslands supporting camelid grazing influence based on the presence of genera such as *Senecio* and *Aciachne* without camelid palatability as well as the decrease of very palatable species from Cyperaceae family (Harris 2010; Klein et al. 2004; Muñoz and Faz 2014). Several genera and species of grasses such as *Carex bonplandii, Espeletia, Hypericum,* and *Rumex acetosella* have been considered as disturbance grazing indicator in the Venezuelan paramo (Mahaney et al. 2007). These authors found that the low species richness could be explained based on the disturbances caused by grazing.

4.6 Use and Management of Altitude Grasslands—Human Effects: Grazing, Land-Use Changes, and Fertilization

Mountain landscapes are also among the most fragile landscapes on earth and are sensitive to both anthropogenic and natural forces. Human activities are significantly modifying biogeochemical cycles in many ways. Changes in the land use and management are recognized as key drivers on global C dynamics (Houghton et al. 1999; Wang and Fang 2009). Forest cover, agricultural practices, grazing, urbanization, and road construction have important and spatially extensive effects on runoff, which then controls rates of erosion and sediment movement. These effects are not unique to the Andes, but are especially interesting in the Andes because of the intensity of human occupation and the special natural and cultural characteristics of Andean highland environments (Harden 2006).

As in the paramo, the scarcity of trees in the drier puna grasslands of the central Andes is thought to result from anthropogenic burning and forest removal (Gade 1999; Harden 2006). Both in the central Andes and in the wet paramo, the cultivation system is based on long fallow periods with grazing and short crop periods. The intensification of land use raises the question of dynamics of the SOM and consequences on soil stability and soil erosion. Andean ecosystems are subjected to accelerated transformations with intensified cultivation and continuous expansion of the fallow agriculture frontier (Hofstede et al. 2002; Bottner et al. 2006).

The Andean region is undergoing transition to agricultural activities such as potato farming and cattle grazing in many areas. There is a lack of data quantifying the contributions of these land uses to soil erosion and nutrient losses. According to Otero et al. (2011), potato farming had more severe impacts on soil quality compared to that of pastoral land use. They found that soil preparation for agriculture often releases part of the immobilized or captured nutrients and alters the soil physical, chemical, and biochemical properties. The volcanic ash soils have little exchangeable Al, even at pH 5, which is likely due to strong bonding of Al with SOM and formation of Al–humus complexes. The variable charge characteristics make pH an important determinant of the soil's nutrient-retention properties. Management practices that change the pH are therefore likely to affect the fate of plant nutrients in the soil (Zehetner and Miller 2006).

Vera et al. (2007) assessed that one of the land-use change consequences is a change in the SOM cycle with a greater degree of maturation in the disturbed soils. The moder humus comes from undisturbed forest soils and it is transformed into an acidic mull in the anthropogenic disturbed soils. Consequently, paramo ecosystems with increasing agricultural settings are being deteriorated, also because these high-altitude ecosystems have low resilience and it is slowly recovered. Conversely, Sarmiento and Bottner (2002) suggested that Andean agricultural systems are commonly used for the cultivation of potatoes and cereals with long fallow periods which leads to an increase in the labile C and N pools and microbial biomass. It represents more carbon and nitrogen availability for microorganisms and plants and could trigger the soil fertility restoration. A very high stability of the OM in these mountain soils was also revealed. Its implications for the agricultural sustainability should be discussed taking into account the traditional soil management.

In many cases, ecosystems in the central and southern Andean highlands are degraded as a consequence of anthropogenic activities such as the change in soil use and unsuitable water management in addition to excessive cattle grazing (Rocha and Sáez 2003; Muñoz and Faz 2012). Many grazing practices are aimed at ensuring the sustainable use of rangelands for livestock production. However, many ecosystem components and processes like plant community structure, soil properties, and nutrient cycling are also affected by grazing management (Schuman et al. 1999; Ganjegunte et al. 2005). Lack of a clear relationship between grazing practices and SOC has been attributed to soil variations, depth of soil sampling, and insufficient evaluation of C distributions within the grazing system. However, the grazing effects in the SOC reserves could be associated with the proportion of stable humic substances in the soil (Galantini and RoselI 2006; Ganjegunte et al. 2005).

Some authors observed that a long-term grazing exclusion by cattle and sheep promoted enrichment of the labile soil carbon pool in semiarid steppes (Shrestha and Stahl 2008). The animal grazing in highlands generally causes a reduction in soil respiration rate, as described by Cao et al. (2004). They reported that soil CO_2 efflux at the lightly grazed site was almost double compared to the heavily grazed site during the growing season in an alpine meadow in the Tibet plateau. Based on C study carried out in the Bolivian Andean grasslands, Muñoz and Faz (2012) concluded that domestic camelid grazing could be affecting the C reservoirs and as a consequence the maturity and stability of these ecosystems.

Conversely, grazing lands may have a high carbon sequestration potential if the input of OM into the soil and the reduction of SOM decomposition are promoted through best management practices (Batjes 1999). In many of the grazing lands, soil receives low carbon input and tends to show an exhaustion degree as a consequence of unsuitable grassland management (Shrestha and Stahl 2008). Therefore, preventing the decrease of the SOM stabilization degree and bringing camelid cattle overexploitation under control is essential to protect the high-altitude ecosystems in the Andean plateau.

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Chapter 5
Species Diversity and Use Patterns of the Alpine Flora with Special Reference to Climate Change in the Naran, Pakistan

Shujaul Mulk Khan and Habib Ahmad

5.1 Introduction

This chapter provides an introduction to the study area and its main physiographic and floristic features with reference to present vegetation study and sampling locations. The various mountain ranges that are collectively known as the Himalayas stretch for some 2500 km across five central Asian countries and comprise one of the earth's most complex, diverse and remarkable biomes, characterized by a comparatively harsh climate, a strong degree of resource seasonality and diversity of both plant species and communities (Kala and Mathur 2002; Oommen and Shanker 2005). Existing in the range of world's largest mountain ranges, north-western Pakistan is one of the places having high phytogeographic and floristic importance. Due to their location, rugged landscapes and critical geopolitical situation, however, many of the more remote mountainous valleys in this region have not yet undergone detailed vegetation studies. Furthermore, most of the botanical accounts that have been published comprise qualitative data without proper quantification (Dickoré and Nüsser 2000; Ahmad et al. 2009; Signorini et al. 2009; Khan et al. 2013a; Khan 2013). Far less effort has been made to provide quantitative descriptions of the plant communities along geo-climatic, environmental gradients in order to elucidate the main determinants of local or regional vegetation patterns (Dasti et al. 2007; Malik and Husain 2008; Wazir et al. 2008; Saima et al. 2009; Khan et al. 2011; Khan et al. 2013b).

The Naran is a mountainous valley in the western Himalayas situated in Pakistan, some 270 km from the capital, Islamabad (34°54.26′ N to 35°08.76′N latitude and 73°38.90′ E to 74°01.30′ E longitude; elevation range 2450–5000 m above mean sea level). The entire area is formed by crosswise ridges of mountains on either side of the river Kunhar which flows in a north-east to south-west direction down the

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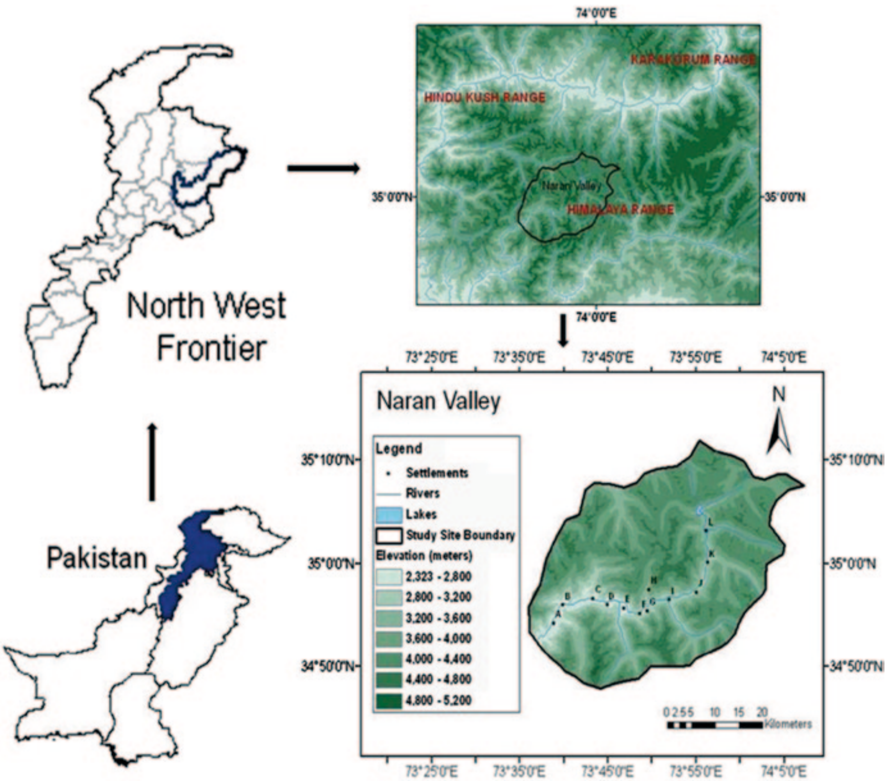

Fig. 5.1 Maps showing the location of the project area, the Naran valley, with respect to Pakistan and the three largest mountain systems (the Himalayas, Hindu Kush and Karakorum), and the altitudinal range and position of the 12 sampling localities (*A–L*) in the valley (see Chaps. 4 and 5 for more detail)

valley to the town of Naran. The river Kunhar has its source at Lake Lulusar near the Babusar Pass at an elevation of 3455 m. It is bounded on the south-east side by Azad Kashmir, on the north by Chilas and Gilgit agencies and on the west by Kohistan and Battagram districts and Mansehra Tehsil. It forms the most northern part of British India and is now a part of the District Mansehra, Khyber Pakhtunkhwa, Pakistan (Figs. 5.1 and 5.2). Geographically, the Naran valley is located on the extreme western boundary of the Himalayan range, from where after the Hindu Kush range of mountains start to the west of the river Indus. Floristically, the valley has been recognized as an important part of the western Himalayan province with some vegetation features that are Sino-Japanese in nature due to the influence of the rain-bearing monsoon winds (Ali and Qaiser 1986; Takhtadzhian and Cronquist 1986).

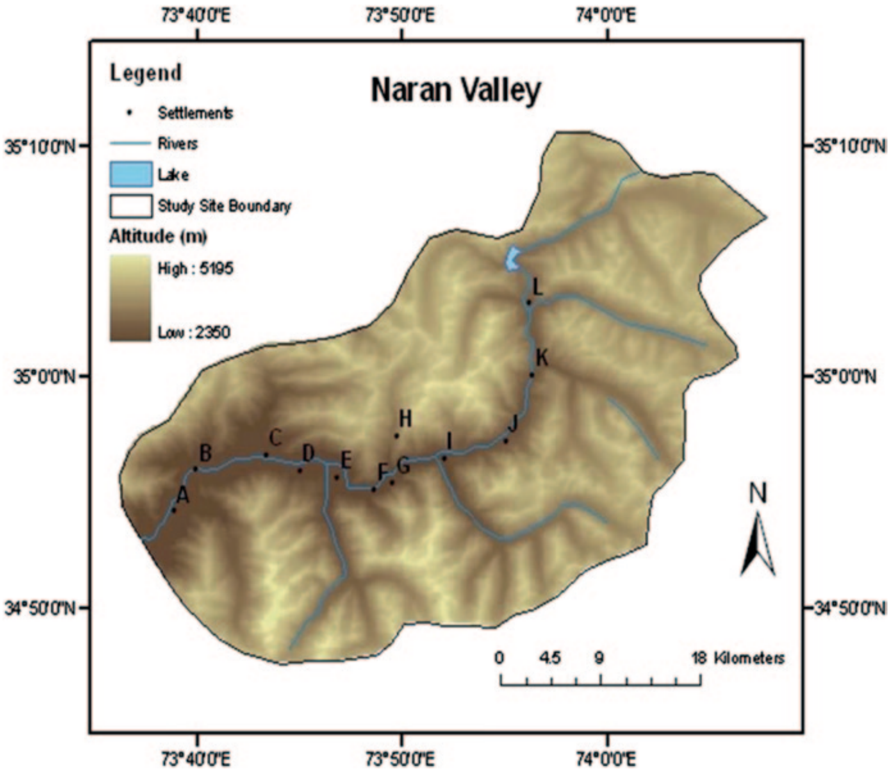

Fig. 5.2 Map of the Naran valley (project area) showing elevation range and location of its settlements (*A–L*) nearby which phytosociological and ethnobotanical surveys were carried out. (Elevation data were obtained from the ASTER GDEM, a product of METI and NASA). *GDEM* Global Digital Elevation Map, *METI* Ministry of Economy, Trade, and Industry, *NASA* National Aeronautics and Space Administration

5.2 Geology

The 2500 km-long Himalayan range resulted from a continental collision between the Indian and Eurasian plates about 60 million years ago, causing an uplift process which is continuing even today. The Naran valley is situated on the extreme north-western margin of the Indian Plate (Fig. 5.3). The rocks of the valley can be subdivided into basement rocks of amphibolites, marble, dolomite, quartzite and deformed granite (O'Brien et al. 2001; Foster et al. 2002; Wilke et al. 2010). Geologically, the area is very important as the Kaghan/Naran ultrahigh-pressure (UHP) assemblage is at the exposed leading edge of the Indian Plate continental crust, where it is still colliding against the Kohistan arc of the Eurasian Plate (Parrish et al. 2006; Clift et al. 2008).

Fig. 5.3 Map showing the location of the project area with respect to its regional geological setting; the Naran valley is located at the junction of the Indian and Eurasian plates. (http://eol.jsc.nasa.gov/handbooks/arabianpages/platesmap.jpg)

5.3 Climate

Monsoon winds are the main source of precipitation and also a primary force controlling erosion and climatology and hence topography and vegetation in the Himalayas. In the western Himalayas and especially in the Naran valley, high mountains situated at the opening of the valley act as a barrier to the incoming summer monsoon from the south and limit its penetration into the upper northern parts of the valley (Clift et al. 2008; Syed et al. 2010). Thus, summers remain cool and relatively dry and most of the valley has a dry temperate climate with clear seasonal variations. Total average annual precipitation is low at only 900–1000 mm but there is heavy snowfall in winter which may occur at any time from November to April (average annual snowfall is 3 m). The range reflects a sharp increase in depth of snow with increasing altitude. There is a distinct wet season in January–April, whilst the driest months of the year are June–November (Fig. 5.4).

Most of the year, the monthly average temperature remains below 10°C. December, January, February and March are the coldest months during which temperatures remain below freezing. June–August is the main growing season, with average daytime temperatures in the range 15–20 °C (Fig. 5.5). Melting snow (May–September)

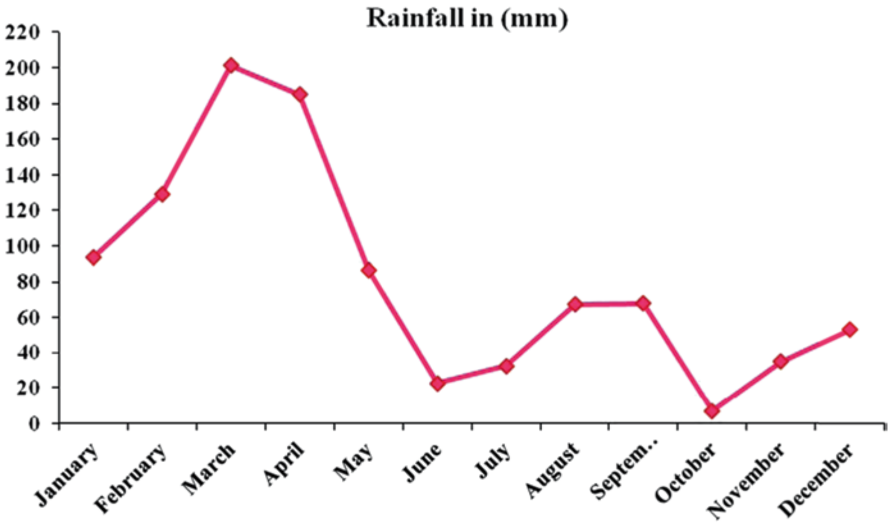

Fig. 5.4 Average monthly rainfall recorded in the Naran valley over the period of 10 years, 1998–2008. (Source: Department of Metrology Islamabad, Pakistan)

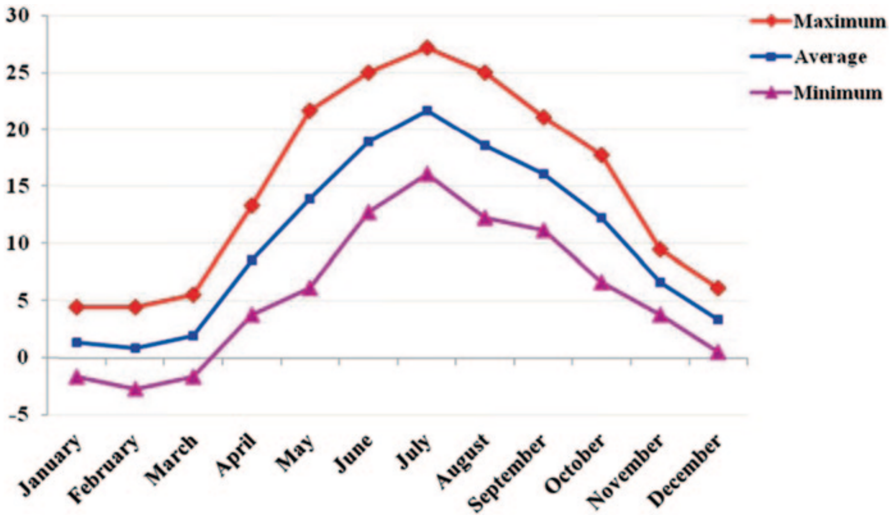

Fig. 5.5 Monthly minimum, maximum and average temperatures recorded at the town of Naran in the southern part of the valley (recorded at an altitude of 2450 m) for the years 1998–2008. (Source: Department of Metrology Islamabad, Pakistan)

is the main source of water for both plant growth and the river Kunhar and also gives rise to avalanches at the onset of summer which not only disrupt travel in the valley but also cause enormous erosion to habitats and damage to the vegetation (De Scally and Gardner 1994) (Fig. 5.6).

Fig. 5.6 Picture showing avalanche near the village of Damdama (near the settlement '*B*', is referred to, on the area map, Figs. 5.1 and 5.2) in the Naran valley; the snow has been excavated to make way for traffic

5.4 Biophysical Environment

Ecosystem studies of habitat types have not been undertaken extensively in Pakistan, especially in the Himalayan valleys. Champion and Harry (1965) described for the first time the forest types of Pakistan, using the following broad categories: swamps, dry subtropical forests, tropical thorn forests, subtropical pine forests, Himalayan moist temperate forests, Himalayan dry temperate forests, subalpine forests and alpine scrub. Beg (1975) defined major habitat types as tropical swamps, tropical thorn forests, tropical dry deciduous forests, subtropical semi-evergreen forests, subtropical forests, moist temperate forests, dry temperate forests, subalpine forests, alpine vegetation and cold desert. All of these vegetation types, except the swamps, are represented in the northern part of the country (Champion and Harry 1965; Beg 1975).

The Naran valley is situated on the extreme margin of the western Himalayas and thus forms a part of the internationally recognized western Himalayan floristic province of the western Asiatic subregion of Irano-Turania. Its geographical, geomorphological, geological, climatic and vegetational setting makes it somewhat transitional between the Himalayas, Hindu Kush and Karakorum ranges. This lends particular phytogeographical interest to the valley and its vegetation.

5.4.1 Vegetation

The vegetation of the western Himalayan province is predominantly under the influence of monsoon winds and can be classified into different vegetational zones on the basis of temperature, humidity and altitude (Champion and Harry 1965; Takhtadzhian and Cronquist 1986). A brief description of the habitat types that occur within the Naran valley and their associated vegetation is provided below.

Fig. 5.7 The Naran valley showing moist temperate forests/habitats (in between the settlements '*A*' and '*B*', is referred to, on the area map, Figs. 5.1 and 5.2) at relatively low elevations and mostly confined to north-facing slopes

5.4.1.1 Moist Temperate

Evergreen forests with some mixture of deciduous broad-leaved trees occur across an altitudinal range of 2400–3100 m above sea level (asl); they are found as far north as the middle of the valley, mainly occupying the cooler, moister north-facing slopes. These forests are dominated by conifers, in particular *Pinus wallichiana, Abies pindrow, Cedrus deodara* and *Picea smithiana.* The understory vegetation consists of both evergreen and deciduous species, amongst which the shrub species *Viburnum grandiflorum, V. cotinifolium* and *Sorbaria tomentosa* are important. Dominant herb species include *Achillea millefolium, Impatiens bicolor, Fragaria nubicola, Geranium* spp., *Viola* spp. and *Plantago* spp. (Fig. 5.7). This vegetation also provides a suitable habitat for the unique animal species.

5.4.1.2 Dry Temperate

This habitat type is the most characteristic of the Hindu Kush mountain range, but also occurs in the inner ranges of the Himalayas and the Karakorum in the north-west. In the Naran valley, this habitat is characterized by patchy shrubby species of *Artemisia, Ephedra, Cotoneaster, Rosa* and *Rubus* spp. at elevations of 2600–3100, particularly in the inner valley. Amongst the tree species of this zone, *Juniperus excelsa* and a few evergreen species of *Pinus wallichiana, Cedrus deodara* and *Picea smithiana* are important. This habitat type receives usually low rainfall in summer and heavy snowfall in winter (Fig. 5.8) and is usually subjected to intense grazing and also partial use by Markhor (*Capra falconeri*) in the winter (Champion and Harry 1965).

Fig. 5.8 Dry temperate vegetation/habitat, which mainly dominates in the middle section of the valley on southern slopes (picture was taken near the settlement '*G*', is referred to, on the area map, Figs. 5.1 and 5.2)

Fig. 5.9 Subalpine vegetation/habitat occupies a relatively narrow zone and is replaced at higher altitudes by alpine grassland (picture was taken near the settlement '*K*', is referred to, on the area map, Figs. 5.1 and 5.2)

5.4.1.3 Subalpine

This habitat type occupies a narrow zone between the coniferous tree line and the alpine pastures. The elevation range of this zone varies slightly from place to place, but is usually in the range 3100–3500 m. Important flora of this zone include *Betula utilis* at the tree line, along with species of *Juniperus, Rhododendron, Primula, Bergenia* and *Poa* (Fig. 5.9). This habitat type is important for snow partridge (*Larwa larwa*) and western horned tragopan (*Tragopan melanocephalus*).

5.4.1.4 Alpine Pastures

This habitat type starts between 3300 and 3500 m where the coniferous tree line ends and the subalpine habitat merges in grasslands up to the altitude of 4500 m

Fig. 5.10 Alpine pastures above the tree line (picture was taken at an altitude of 3600 m near the settlement '*E*', is referred to, on the area map, Figs. 5.1 and 5.2)

or above. This is a relatively productive habitat type and people use it for livestock grazing and collection of non-timber products during the summer months. The vegetation is dominated by a number of herb species, including species of *Potentilla, Anemone, Gentiana, Poa, Polygonum, Iris* and *Aster* (Fig. 5.10). This habitat is typically inhabited by snow partridge (*Larwa larwa*) and Himalayan ibex (*Capra sibirica hemalayanus*).

5.4.1.5 Cold Desert and Permanent Snow

These habitat types are found at the highest altitudes on only a few peaks in the valley. The vegetation of cold desert habitat is xerophytic in nature and emerges only for a very short growing period following snow melt. Typical plant species associated with this habitat type include *Gentianod* and *Polygonum* spp. Snow partridge (*Larwa larwa*) and Himalayan ibex (*Capra sibirica hemalayanus*) are found on the periphery of this habitat (Fig. 5.11).

5.4.2 Kunhar River

The Kunhar is the main river of the Naran valley. It originates from Lake Lulusar and is joined by several other small tributaries (*nalhas*) at various locations on its journey, including the Gittidas Nalha, Jalkhad Nalha, Burwai Nalha, Wettar Nalha, Jora Nalha, Dadar Nalha, Shanak Nalha, Sapat Nalha, Kinarida Nalha, Barjalida Nalha and the Saiful Maluk Nalha. The main sources of water to the main river and its tributaries are melting snow and natural springs, with a smaller contribution from rainfall during the summer (Fig. 5.12).

Fig. 5.11 Cold desert/permanent snow on the highest peaks in the valley. These habitats retain snow cover throughout much or all of the year and thus have an extremely short growing period (picture was taken above the settlement '*F*' at an altitude of 4500 m, is referred to, on the area map, Figs. 5.1 and 5.2)

Fig. 5.12 The river Kunhar flowing near the village of Soach in the Naran valley (picture was taken from an altitude of 4000 m, above the settlement '*C*', is referred to, on the area map, Figs. 5.1 and 5.2)

5.4.3 Lakes

The Naran valley is also known as a 'land of lakes' due to the presence of nine lakes in the valley. The most important amongst these are Lake Lulusar, Lake Saiful Maluk, Dhodipatsar Lake, Anso Jheel (Lake), Jati Jheel and the Jalkhad Lake (Census Report 1998). Further information on the two more spectacular and largest lakes, Lakes Lulusar and the Saiful Maluk, are given below.

5.4.3.1 Lake Lulusar

Lake Lulusar near the Babusar Pass is a beautiful, natural lake surrounded by the mountains from all sides and located at an elevation of 3455 m. It forms the source

Fig. 5.13 Lake Lulusar: the source of the river Kunhar and the end point of the Naran valley, western Himalayas (near settlement '*L*', is referred to, on the area map, Figs. 5.1 and 5.2)

of the river Kunhar and also the upper limit of the Naran valley. This is an irregular shaped lake about 300 m wide and 2.5 km long (Fig. 5.13). The Naran valley is blocked at the end of the lake by high mountains, but a pass allows a rough way to cross over into the Chilas valley (a tributary valley of the Indus River). This is the 4173 m-high Babusar Pass which provides views of the Nanga Parbat (The Naked Mountain, 8126 m).

5.4.3.2 Lake Saiful Maluk

Lake Saiful Maluk is one of the most famous and beautiful lakes in the Himalayas. It is about 500 m long and 460 m wide, situated at an elevation of 3220 m, near Naran town in a tributary valley and in the shadow of the Malika Parbat (Queen of the Peaks, 5290 m). It gives rise to the Saiful Maluk stream (*nalah*), which merges with the river Kunhar at the edge of Naran town. It is an important tourist spot in the valley and people come to see the spectacular scenery and hear the local legend about the prince Saiful Maluk who fell in love with a fairy named Badri Jamala (Fig. 5.14).

5.4.4 Peaks

There are a number of peaks in the Naran valley, amongst which the highest is the Malika Parbat which rises on the north-eastern boundary of Lake Saiful Maluk, to an elevation of 5290 m (Fig. 5.15). Other high peaks are Shikara and Bichfa (both having a height of 4877 m), and Bogi and Raja with heights of 4852 and 4720 m, respectively (Fig. 5.16).

Fig. 5.14 The Lake Saiful Maluk situated at a distance of about 6 km from the Naran town (settlement '*A*', is referred to, on the area map, Figs. 5.1 and 5.2) is one of the region's most beautiful lakes and a famous tourist spot

Fig. 5.15 The Malika Parbat (Queen of the Peaks, 5290 m) is situated immediately to the north-east of Lake Saiful Maluk

Fig. 5.16 The Bogi peak (4852 m) (picture was taken near the settlement '*J*', is referred to, on the area map, Figs. 5.1)

Fig. 5.17 View from Lalazar near Batakundi, taken in early August 2009, showing crop fields of potatoes and peas (picture was taken near the settlement '*D*', is referred to, on the area map, Figs. 5.1 and 5.2)

Fig. 5.18 Crop fields at the Batakundi research station showing peas and potatoes at the end of July 2010 (near settlement '*E*', is referred to, on the area map, Figs. 5.1 and 5.2)

5.5 Agro-Ecology and Important Agricultural Crops

The harsh climate in this high altitude valley means that the growing season is reduced to a very short summer and hence agricultural activities are limited. The whole area is mono-cropic, i.e. only one crop can be grown in a year, and only summer (kharif) crops are cultivated. The main crops are potatoes and peas. Recently with the help of Germany, the government of Pakistan has established a research station at the Upper Batakundi village, for the production and provision of potato seeds (tubers) to the local farmers (Figs. 5.17 and 5.18).

Other crops are maize, rye, fodder, wheat, beans and cauliflower, but with less frequency and production. Fruit trees, including pears, plums, walnuts and apples, are also grown in the area but less frequently. A lack of financial support and poor communication and transport links are the main hurdles to improved practices of

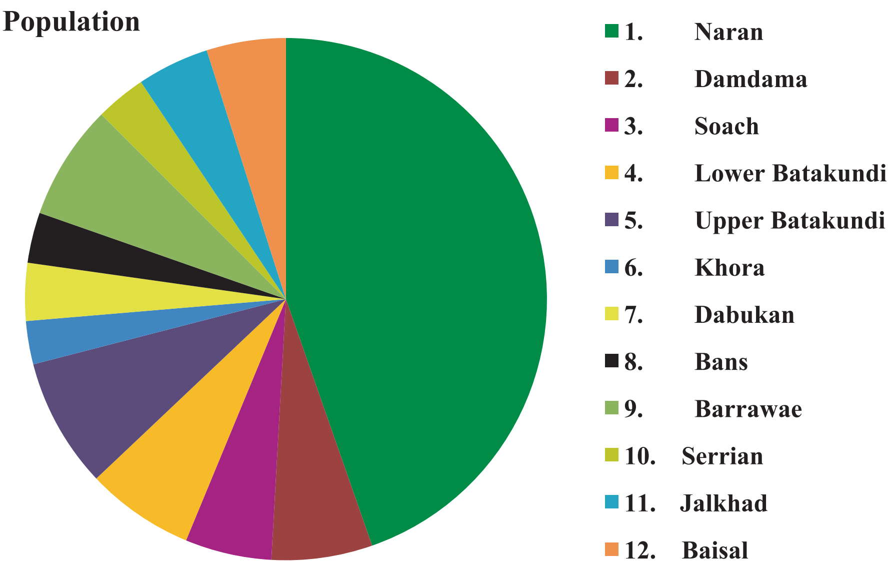

Fig. 5.19 Distribution of total human population of about 22,000 amongst the 12 main localities of the Naran valley, western Himalaya, Pakistan

land development and agriculture. The river Kunhar and its tributaries provide water for irrigation in summer, whilst natural springs and streams are the main sources of drinking water (Fig. 5.18).

5.6 Demography of the Main Villages of the Valley

The population of the Naran valley is exclusively rural, and mostly people live in temporary settlements and even in tents in the upper parts of the valley due to the prevailing high levels of poverty. The local economy is mainly based on farming and rearing of livestock. Although exact data on the population of this area are not available because most of the inhabitants are seasonal migrants or nomads and their number varies according to the season, it is believed that approximately 22,000 people inhabit the valley each year (Fig. 5.19).

5.7 Main Localities (Villages of the Valley)

Severe winter weather compels the inhabitants of the Naran valley to follow a nomadic lifestyle, with many people making temporary arrangements to reside at high altitudes during the summer months and returning to lower altitudes during the winter. The following sections provide brief descriptions of some of the more important villages/localities of the area.

5.7.1 Naran Town

The name of the valley is attributed to the small beautiful Naran town situated at the junction of the river Kunhar and the Saiful Maluk stream (34°54.423′ N latitudes 073°39.034′ E longitudes, 2451 m). About half of the population of the valley (10,000) reside in the Naran, which not only serves as a base for the whole valley but also as the entry point to the tributary valley of the Lake Saiful Maluk. From here one can ride a jeep or horse or hike on foot to several picturesque lakes, tributary valleys, landscapes and peaks. The people of Naran town are semi-nomads and most of them migrate to the plains during the winter season. The economy of the residents is primarily based on agriculture, domestication of animals and trade in forest products, whilst some also own restaurants, hotels and shops. There are a few watermills and a small power station. Tourists come for picnics and to stay in the Naran during the summer season.

5.7.2 The Lower and Upper Batakundi

The economy of these two villages (34°55.180′ N latitudes and 073°46.620′ longitudes (lower) and 34°55.250′ N latitude and 073°46.660′ (upper), 2610 and 2540 m, respectively, is based on farming and rearing of livestock. Potatoes and peas are cultivated widely as both the villages occupy much of the plain area compared to other localities. The main source of irrigation is the river Kunhar, its tributaries and springs. Each village has two primary schools, each for boys and girls.

5.7.3 Barrawae

Barrawae village (34°56.344′ N latitudes 073°52.034′ E longitudes, 2903 m) is located in a region that is under the ownership of Muzamil Shah, a lord (Syed) of the Kaghan. There are primary schools for boys and girls. The people are nomadic, dwelling in the area during the summer and returning to the lower villages of Kaghan, Mhandri and Jarid during the winter months (Figs. 5.20, 5.21, 5.22).

5.7.4 Jalkhad

Jalkhad village (35°00.065′ latitudes and 073°56.333′ longitudes at 3120 m) is located between Barrarwae and the Baisal. This region is in use of the Pakistani army, whilst the inhabitants include Gujars and Pathans. The economy of the local people is mainly based on livestock raising (goats and sheep), as the climate is less suitable for crop production in the upper parts of the valley, although people also cultivate potatoes and peas, but on a smaller scale compared to the villages lower down the valley. The people migrate to the plain areas during the winter season.

Fig. 5.20 Pictures giving glimpse of the ecotourism; hotels near the Naran village on the bank of the Saiful Maluk stream/tributary

Fig. 5.21 Terrace cultivation (after deforestation) near Upper Batakundi village, July 2009 (picture was taken near the settlement '*E*', is referred to, on the area map, Figs. 5.1 and 5.2)

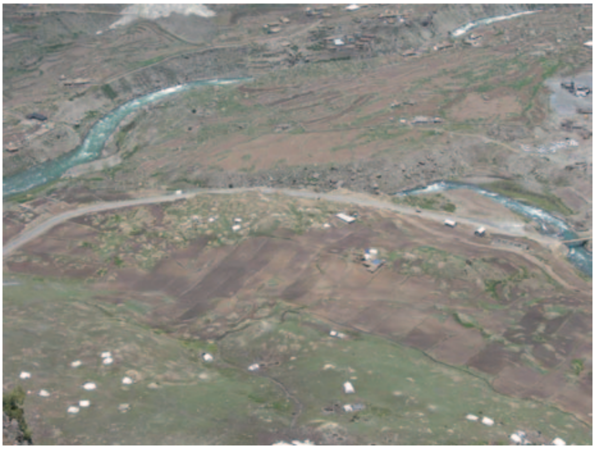

Fig. 5.22 Fields being prepared for potato crops near Barrawae village, June 2010 (picture was taken near the settlement '*I*', is referred to, on the area map, Figs. 5.1 and 5.2)

Fig. 5.23 Tent village of grazers at the Baisal '*L*', is referred to, on the area map (the last village of the valley, above 3200 m)

5.7.5 Baisal

Located near Lake Lulusar at 3220 m (35°02.322′ N latitudes and 073°56.183′ longitudes), this settlement comprises a few grazers/nomads who live here in temporary shelters/tents during the summer. Lake Lulusar is located at a distance of about 5 km from Baisal towards the north (Fig. 5.23).

The names of other main villages referred to in this study are Damdama, Soach, Khora, Dabukan and Bans.

5.8 Ethnology

Various tribes including the Gujars, Syeds, Swati and Kashmiri inhabit the valley. The most important amongst these are the Gujars (descendents of the Indian Aryans) who are famous for their unique culture, way of life, rituals and bravery. The Gujars are concentrated in the upper parts in most of the valleys in Pakistan where they cultivate rain-fed slopes, and are generally more aware of traditional knowledge of plant use and local ecology (Ahmad et al. 2009). The Gujars were designated by the British as a martial race who were thought to be naturally strong in battle, and possessing qualities like courage, faithfulness, autonomy, physical strength, discipline and firmness. They are the original inhabitants of the Indo-Pak subcontinent (Chauhan 1998). Their life is very harsh and, to some degree, comparable to the prehistoric people. They are very hard-working people and easily face any ruthless situation, particularly natural hazards and climatic constraints. They migrate to the upper parts of the Naran valley with their livestock in the summer and come back to the plains during the winter (Lyon 2002). The Gujars have their own specific language called Gujri which is amongst one of the most ancient languages of the world. The origin of Gujri goes back to 400 BC and it has a rich vocabulary.

Fig. 5.24 Herd of sheep and goats grazing on a southern slope immediately after snow melt. Rearing sheep and goats is one of the main sources of livelihood in the Naran valley (picture was taken near the settlement '*D*', is referred to, on the area map, Figs. 5.1 and 5.2)

It is also considered to be the mother tongue of the present-day Urdu and Punjabi languages (Wayne 1996).

Amongst the other main tribes in the Naran region are Swati (who came from the Swat valley about 500 years ago); they are descendants of the ancient Kushan dynasty, and Syeds are the religious people of the area. These tribes in combination form the major population and have inhabited the Naran valley since at least 300–400 years ago (Bellew 1994). Most of the people speak the Gujri or Hindko languages.

5.9 Livelihoods

Human life in the Naran valley is a continuous challenging effort for survival. Usually, people have more than one type of occupation in order to maintain a sustainable livelihood. Usually, every household keeps cattle, the numbers and types of which vary from a few to hundreds. In the lower and middle valley, the second most common profession is growing crops. Most of the people execute these two professions simultaneously. Having cultivable lands and a more moderate climate, people grow crops in the lower valley which gradually decrease along the valley with altitudinal increase and disappear at the valley's upper boundaries. The people of the upper valley mainly rely on rearing livestock and collection of wild plants. Grazing livestock is dominant in the valley (Fig. 5.24).

5.9.1 Mountains Vegetation: A Wider Picture with Respect to Climate Change

Plants and plant communities survive at the edge of life in high mountains all over the world; these are also ecosystems where climatic change is more visible and where species extinction is very rapid (Kullman 2010; Khan and Ahmad 2014). Mountains are the most remarkable land forms on the earth's surface with prominent vegetation zones based mainly on altitudinal and climatic variations. Aspect variation also enhances habitat heterogeneity and brings micro-environmental variation in to the vegetation pattern (Clapham 1973; Shaheen et al. 2011; Khan et al. 2014). High mountains all over the globe are important hot spots for endemic floras (Dirnböck et al. 2001; Vetaas and Grytnes 2002; Casazza et al. 2005, 2008; Fu et al. 2006; Nowak et al. 2011; Halloy and Mark 2003; Kazakis et al. 2007).

Mountain vegetation has manifold functions not only within the mountain system itself but also regionally in the adjacent lowland ecosystems by regulating floods and flows in streams. The Himalayas are the birthplace of ten of the largest rivers in Asia and a large and important carbon sink. Economy of south Asian countries is mainly based on the flow of these rivers from the Himalayas. These rivers ensure food security by providing irrigation water for rice and wheat crops which are the major staple food (Archer and Fowler 2004; Rasul 2010). Regionally, shrubby vegetation of high altitudes also regulates avalanche movements and protects soil (Hester and Brooker 2007). Ecological changes in the Himalayas affect the global climate by bringing about changes in temperature and precipitation patterns of the world. Globally, these mountains also play important role in combating the climate change and greenhouse effects. The diverse Himalayan vegetation ranges from tropical evergreen species in the south-east to thorn steppe and alpine species in the north-western parts (Behera and Kushwaha 2007). At high altitude, the extent of vegetation cover is related to the melting of snow. Irregular loss of its ice might have dangerous rise in world sea levels (Xu et al. 2009). These mountains are extremely sensitive to global climatic change (Thompson and Brown 1992). Such hazardous glimpses have already been observed in the form of flood in Pakistan, India, China and Thailand in the past 3 years. They are also important places for investigating global warming and climate change.

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Chapter 6
High-Altitude Plants in Era of Climate Change: A Case of Nepal Himalayas

Anup KC and Ambika Ghimire

6.1 Introduction

Biodiversity is the combination of all life-forms including their ecological interaction with physical environment and other functional aspects. It includes the genetic diversity, species diversity, and ecosystem diversity. It is the basis of life and plays an important role in nutrient cycling, natural stability, productivity, and evolution of the ecosystem processes. Biodiversity has multiple ecological and economic services as provisioning services (food, water, fiber and fuel, biochemical materials), regulatory (climate, hydrology, pollution control, soil formation, natural hazard and erosion control), and cultural services (educational, recreational). Biodiversity of plants helps in maintaining the global climate by absorbing and storing carbon dioxide during photosynthesis in the form of biomass in its different parts (KC et al. 2014).

Climatic and topographic parameter affects the growth and diversity of living things as a result of which biodiversity varies throughout the earth. The care and management of biodiversity is the most important responsibility of human being to live a safe and healthy life. Hence, biodiversity conservation was prioritized on Earth Summit in June 1992 (Thapa 2010).

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6.2 Biodiversity in Nepal

The geography of Nepal varies in Southeast Asia spreading about 800 km from east to west and 144–240 km from north to south. The position varies from longitude of 80°04’–88°12’ E and latitude of 26°22’–30°27’ N. Geographical diversity varies throughout the country (Fig. 6.1) with 83 % of land lying in mountainous region and 17 % in the terai land (Paudyal 2002).

Nepal has variation in biodiversity due to variation in geography, altitudinal range, and climate. It lies in the central part between eastern and western Himalayas. It integrates paleartic and Indo-Malayan biogeographic regions with major floral species of Asia creating a rich biodiversity in landmass (HMGN/MFSC 2002). It lies at a transition zone comprising six floristic regions. The country is a part of biodiversity hotspot, among four hotspots occurring in the Himalayan region. There are six biomes occurring in Nepal. It hosts nine important ecoregions among 60 ecoregions found in the Himalayan region. Variation in altitude, climate, and vegetation leads to 35 types of forest with 118 ecosystems (GoN 2009). Species richness among floral diversity comprises 771 lichens, 2025 fungi, 807 algae, 1150 bryophytes with 534 pteridophytes, 31 gymnosperms and 6653 angiosperms (GoN 2012).

Differences in physiography lead to variation in biodiversity in Nepal. Diversity of floral and faunal species in mid-hill is due to variation in climate from subtropical to temperate. Increase in altitude results in a decrease in number of species, but high-altitudinal regions are richer than low-altitudinal regions in case of endemic species of flora and fauna. Endemism of flora and fauna is due to hearse topography

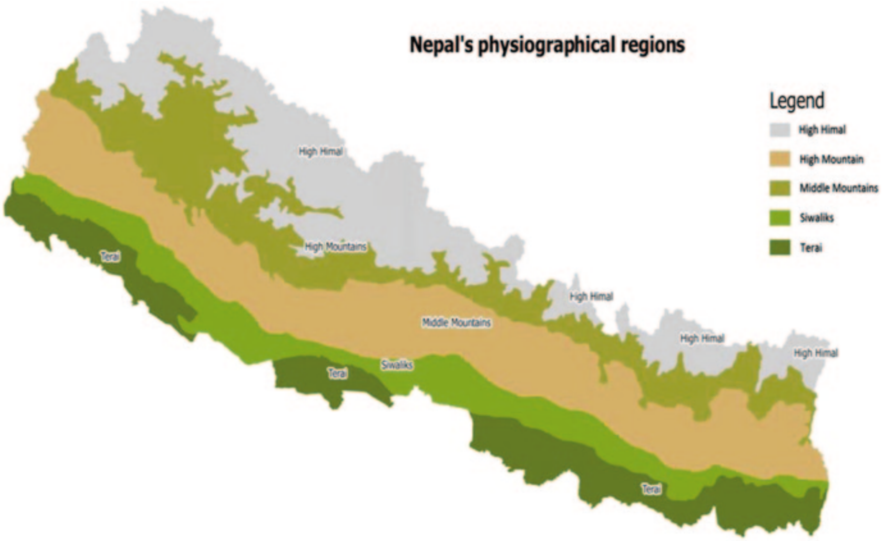

Fig. 6.1 Physiographic regions of Nepal. (FRA/Nepal 2013)

and cold climate. The beta diversity at the level of genera, families, phyla, habitats, and ecosystems is the important feature of mountain biodiversity.

6.2.1 Plant Diversity and Ecology in Nepal

Biodiversity is the variety of life encompassing the total number, different life-forms, ecosystem levels, and combinations existing in the earth. It includes number and variety of living beings from different sources of ecosystem, such as fresh water, marine and terrestrial, marine and freshwater ecosystem (HMGN/MFSC 2002). Due to variation in topography, geology, geomorphology, altitude, and climate, there is great diversity of plants in Nepal varying from lower altitude to higher altitude. According to the large-scale physiographic division, there are different plant species in terai, hill, and highland. On the basis of geomorphology, there is high diversity of plants species along terai, Siwalik and Dun Valley, Mahabharat range, mid-hill, lesser Himalaya, higher Himalaya and trans-Himalayan valleys. Different types of vegetation are found across climate and altitudinal zones ranging from tropical and subtropical evergreen vegetation, temperate broad leaf, and coniferous vegetation and subalpine and alpine vegetation.

6.2.1.1 Diversity of Plants at Different Altitudes of Nepal

The diversity of plants studied in three different regions, namely terai and Siwalik, mid-hills and highlands in the context of Nepal was documented as follows (Table 6.1).

6.2.1.2 Studies on Plant Biodiversity in High Altitude in Nepal

Few studies are carried out for the assessment of plant diversity in high altitude of Nepal. Some of them are listed below.

Study in a mixed *Abies spectabilis* forest of Manang shows high human interference as the main factor leading to the destruction of species of high girth classes. There was less natural regeneration of *Abies spectabilis* due to radiation, low moisture, and high human pressure (Acharya 2004).

Table 6.1 Number of species of flora occurring in each physiographic zone. (Source: BPP 1995)

Groups	Terai and Siwalik	Mid-Hill	Highland
Bryophytes	61	493	347
Pteridophytes	81	272	78
Gymnosperms	–	16	10
Angiosperms	1885	3364	2000

Grau et al. (2007) conducted a study in Central Himalaya, Nepal to assess the species richness of mosses and liverworts for altitudinal difference of 100 m. Strong correlations between richness of the plants were observed. Liverworts have maximum richness at 2800 m, mosses at 2500 m, and fern at 1900 m. The maximum richness of endemic and nonendemic liverworts is at 3300 and 2700 m, respectively. The variation in species richness was due to the climatic variables.

Ghimire et al. (2008) reported three species of tree in a subalpine forest on the southern slope of the dry Manang valley in north central Nepal. In that forest, only *Juniperus indica* was found at the highest altitude on the southern slope. Deforestation has changed species composition and community structure of subalpine forest. The total basal cover of *Juniperus indica* forest was 0.17 % in mixed Juniperus forest. In a pure *Betula utilis* forest of Manang, the basal cover was 2.3 % (Shrestha et al. 2007). In this forest, the basal cover generally increased from 3500 to 4100 m.

Adhikari et al. (2009) conducted a vegetation study in sediments of southern Tibet. It was observed that vegetation in sediments contain alpine trees like Abies, Pinus, Keteleeria, Picea, Tsuga, and Quercus with steppe species like Artemisia, Compositae, Chenopodiaceae, Plantago, and Poaceae. The southern part of Tibet in dry climate was dominated by steppe vegetation.

Tiwari (2010) conducted a study in central Nepal to assess the structure of *Abies spectabilis* in Langtang region with the help of systematic random sampling. *Abies spectabilis* was dominating (84 %) followed by *Rhododendron campanulatum* (5 %). Human related activities such as grazing and firewood harvesting causes decrease in species diversity of the forest. Density of *Abies spectabilis* was decreasing from 3100 to 3550 m and increasing from 3550 m toward tree line. Only 2 % of seedlings of *Abies spectabilis* were developed into saplings.

Bhuju et al. (2010) conducted a research in Sagarmatha region in central Nepal focusing on impact of climatic change in high-altitude forest. *Abies spectabilis* showed bell-shaped diameter class distribution in Pangboche and inverse J shape in Debuche. Analysis of tree core showed that *Betulla utilis* was 100 years and 20 years older than *A. spectabilis* in Debuche and Pangboche, respectively.

Gaire et al. (2010) conducted a research in central Nepal focusing on tree line ecotone in Langtang region with an objective to observe the impact of climate change on ecology. The basal area for tree with *Abies spectabilis* as dominant species was 20.56 m/ha and tree density was 734 trees/ha. The density of sapling was 1.590/ha while that of seedling was 831/ha. The density of sapling and seedling of *Abies spectabilis* was 255 and 350/ha, respectively. Increase in temperature had caused gradual and upward shift of *Abies spectabilis* in Langtang region.

Gaire et al. (2011) conducted a research in Langtang region of central Nepal with an objective to study the tree line dynamics of *Abies spectabilis*. There was negative relation between tree growth and March–May temperature. They predict that there will be upward shifting of tree line in the coming decades.

Krstic et al. (2012) conducted a research in Panch Pokhari Lake, central Nepal at an altitude of 4050 m to assess the diatom flora assemblage composition. The results show that original flora was replaced by new ones and increased nutrient inputs lead to emergence of new taxa.

Shrestha (2013) conducted a study in Nepal to assess response of vegetation to climate change in central Himalaya. It was observed that growth of vegetation was less in tree line due to heavy snowfall in cold season due to delay in growing season. In the current time, tree line was not moving over the whole decade.

Thapa et al. (2014) conducted a research in Khaptad region of western Nepal focusing on influence of climate change on radial growth of *Abies pindrow.* Tree ring analysis shows 362-years-old tree ring of 1650. There was negative relationship of tree growth with temperature of March–May while positive relationship with March–May precipitation.

6.3 Climate Change

Climate change is a change in long-term distribution of weather over longer period of time of many years. Climate change is not a new topic, the process occurred since the creation of the earth and is occurring and will be occurring in the future. But the changes in the past 50 years are dramatic and scientists attribute the change to anthropogenic factors associated with the emission of greenhouse gases (GHG). Over the past 100 years from 1906 to 2005, temperature of earth increased by 0.74 °C, in which half of this increment, i.e., 0.44 °C occurs in 25 years interval from 1970 to 2005. Increase in global average temperatures since 1950 is due to increase in the emission of anthropogenic GHG (IPCC 2007).

6.3.1 Climate Change in Nepal

Major parts of the Hindu Kush Himalayan area are getting warmer with increase in temperature of more than 0.01 °C per year. But, the higher Himalayan data from Nepal over the period from 1977 to 1994 showed an increase in annual temperature of up to 0.06 °C (Shrestha et al. 1999). Temperature is much warmer in eastern part of Tibet and Nepal with annual rise of more than 0.02 °C. Temperature was increasing about 0.015 °C per year from December–February in winter months which was more than the annual average rate (Singh et al. 2011). Warming in the Himalayas is demonstrated by the increased rate of glacial recession and the resultant formation of new glacial lakes in the higher Himalayas (KC 2012). Heavy rainfall and storms have increased throughout Nepal indicating overall increase in precipitation. The change in pattern of precipitation is less compared to that of temperature in the case of Nepal (Singh et al. 2011).

According to the report of National Adaptation Plan of Action (NAPA)/Ministry of Environment (MOE) (2010), GHG emission potential of Nepal is 0.025 % of annual global GHG emission. But the population is about 0.4 % of global population showing that the share of Nepal toward climate change is very low. However, the vulnerability position of Nepal in the world is fourth. Increase in the temperature of high mountains is causing heavy snowmelt resulting in decreasing area of glacier and increasing dry spell of water resources (Shrestha et al. 1999).

In Nepal, fish farming, agriculture, forestry sectors are highly vulnerable to the impacts of climate change causing decrease in the productivity of crops. This will result in a decrease in production of food crops, energy, livestock, and forest products (FAO 2007). Intergovernmental Panel on Climate Change (IPCC; 2007) has listed three key sectors: food and fiber, land degradation, and biodiversity as the most important sectors to the climate change vulnerability in the South Asian region. Rural communities are most vulnerable to the impact of climate change due to the availability of few resources to cope with extreme weather events like landslides, erosion, and drought particularly in the mountain and flooding, sedimentation and drought in the lowland regions of Nepal. There will be pressure on ecosystem functioning and social factors of the environment in Nepal due to the variation in climatic parameters. There is great threat of bursting of 24 glacier lakes situated in Nepal due to global warming. Climate change causes reduction of snow cover in the mountains, decrease in water quantity, rise in forest fire disaster, extreme weather phenomenon, decrease in irrigation potential, and water table (Regmi 2009).

6.3.1.1 Impacts of Climate Change on High-Altitude Plants

High-elevation ecosystems of Himalayan region are the most vulnerable geographic regions of the world to climate change after the polar region (Cavaliere 2009). Subalpine forest represents the uppermost forest ecosystems along the elevation gradient in ecosystems. They are vulnerable not only to variation in climate but also to high anthropogenic pressure (Sharma et al. 2009).

Among all the parameters which describe a mountain environment, altitudinal gradient is the most apparent and conceivable one. The air temperature falls by 0.6 °C per 100 m on an average along the altitudinal gradient. Therefore, the changes in climate will be much more pronounced and the changes in vegetation can be easily detected in a mountainous environment along the altitudinal gradient. Himalayas cover about 3 % of the earth surface and are home to 10,000 species of plants, which makes the alpine ecosystem among the most diverse and unique in the world. During the period between 1977 and 2000, warming in Nepal was around 0.6 °C per decade (Shrestha et al. 1999).

Ecological study of subalpine forest in the Nepal is very less, though some initiatives have been taken in recent time. Various observations from the past experimental studies, current ecophysiological and ecological understanding show that forests are highly sensitive to climate change. A slight increase in the mean annual temperature of 1 °C is sufficient enough to bring substantial changes in the growth and regeneration capacity of many tree species. With climate change, the suitable habitats for many species are likely to shift in high altitudes faster than the normal rate at which many species can migrate and establish. Global models based on a doubled carbon dioxide predict that a substantial fraction of the existing forests will have to change from the current vegetation types to new vegetation types (Kirschbaum and

Fig. 6.2 *Betula utilis* forest near the tree line in Manaslu region

Fischlin 1966). The native species in higher altitudes which are surviving in cold climate are affected badly by the global warming phenomenon. Dominant species on lower altitude are shifting toward higher altitude to adapt to the increasing climate change scenario, bringing competition to the high-altitude species.

In the mountain ecosystem, community pattern varied according to the altitude. Generally, it can be noticed that mountain ecosystems usually have distinct ecology and living communities with more number of endemic plants and animals due to geographical variation with increase in altitude. Unique and varying climatic parameter in mountain is influencing diversity of plant species. Other factors such as topography, soils, postglacial succession, and human disturbances also affect the vegetation pattern. Community structure is directly regulated by species diversity and it is the biological basis to maintain ecosystem functions (Tiwari 2010).

6.3.1.2 Tree Line Shifting in the Himalayas Due to Climate Change

The tree line is the highest altitude in the mountain at which a tree of 2 m is growing upright. It indicates lower belt of alpine region that vary from place to place mostly due to change in climatic parameters (Bhuju et al. 2010). It is also taken as an important indicator for determining climate change.

Change in climatic parameters affects the functioning of biological system in different ways. Shift in tree line, change in behavioral pattern, disappearance of species, and phenology are the biological impact in the ecosystem level from global warming. To adapt from the rise in temperature in lower belt, critical plants shift toward higher elevation. Growth and distribution of alpine species will be affected by upward movement of tree line. It would shift the plants in higher altitude which will be more than the adaptive capacity of plants at that altitude. It would bring drastic change in forest type and composition and disturbance in forest conservation and management (Shahi 2011).

Forest diversity will be changed and moved upward to higher elevation due to climatic variation in Nepal. The forest ecosystem may be subjected to long-term disturbance due to the transition situation of environmental parameters. The tree line is unique which consist of subalpine vegetation in lower belt and alpine vegetation in upper belt. The timing of plant growth and temperature affect the tree line. Global warming will shift the tree line upward, shifting the habitat of wild animals causing disturbance in their normal living condition. Rise in temperature by 1 °C will cause upward shifting of tree line of about 150 m. Tree line shifting was already observed in western Himalayan belt of Nepal in Gorkha, Mustang, and Manang area (Gupta 2010).

Increase in atmospheric temperature, forces the alpine plants to migrate to higher altitudes which are known by a phenomenon called summit trap. Mountains are the rich repositories of biodiversity and home to many of the endangered species. In mountains, vegetation rapidly changes with change in elevation so these areas are suitable for assessment of climate change and its associated impacts (Whiteman 2000). The response of ecosystems at tree line in mountain regions has a great importance. The timberline will change in coming decades by changing the visible boundary of vegetation in high altitude. Tree line positions have a strong connecting linkage with climatic variables and these areas are sensitive to global warming and phenomenon of climate change. So, it can help in the detection of climate change acting as a suitable indicator (Grace et al. 2002).

The location of tree line in higher altitude varies from place to place and depends on the location of the snow line. Trees present in the upper ecotone areas are found to be more vulnerable to warming temperature. Potential specimen of tree line species helps us to study the variations in climate through analyzing the tree ring data (Bhattacharyya et al. 2006). The past climate in an area can be detected from the change in growth of tree species, which can be estimated with the application of dendrochronology. The pronounced impact of climate change on growth of trees especially due to temperature is illustrated by the study of growth ring samples from the tree line areas (Hughes 2002). Studies done in the upper tree line areas of western Himalayas shows that the Himalayan pine (*Pinus wallichiana*) is sensitive to climate change.

6.3.1.3 Studies on Tree line Shifting in Nepal

There are very few studies done on tree line shifting as an indicator of climate change in Nepal. Few studies are carried out in Sankhuwasava district in eastern Nepal, Langtang National Park and Sagarmatha National Park in central Nepal, and Manaslu Conservation Area in western Nepal.

Vijayaprakash and Ansari (2009) conducted a research in eastern Nepal to assess the tree line shift of *Abies spectabilis* in Sankhuwasava district, comparing both the aspects of north-facing and south-facing slope. The result shows that the tree line vegetation is shifting at a faster rate, i.e., 23 m in 10 years in the southern aspect

Fig. 6.3 Tree line below the Himalayas in the Manaslu region

while it is 17 m in 10 years in the northern aspect. The difference in minimum and maximum temperature had increased during the period 1977–2007. The different growth parameters like age, diameter at breast height (DBH), and height of the dominant trees were found to be decreasing with an increase in altitude in both the aspects. It has been found that growth is more in south-facing slope than in the north-facing slope. An estimation of the basal area of trees in each plot showed that the basal area is showing a decreasing trend along the elevation gradient. The regeneration survey in the study area showed that there is no marked difference in the regeneration of *Abies spectabilis* and *Juniperus macropoda* between the northern and southern aspects.

Suwal (2010) conducted a study in central Nepal to study the tree line shift of *Abies spectabilis* in Manaslu area. The tree line was seen at an altitude of 3841 m in 2007 with a shift of 34.29 m per decade. There was faster growth of seedlings below tree line which might be due to climate change.

The tree line had shifted upward in Manaslu Conservation Area of central Nepal as a response of climate change in the recent decades. The *Abies spectabilis* and *Betula utilis* species was seen moving toward higher altitude that the past results according to the study report of National Academy of Science and Technology (NAST) Shahi (2011).

Gaire et al. (2013) conducted a research throughout Nepal focusing on tree ring analysis and its future prospects. The oldest *Tsuga dumosa* tree was of age 1141 years in higher altitude of Nepal. There was upward shift in tree line of *Abies spectabilis* comparing to the past.

Species biodiversity depends on climatic factors and land use parameters. It decreases with decrease in air temperature and rainfall (Gupta 2010). Historic relationship between living things and climatic parameters will be affected seriously if changes in climatic parameters occur faster than the functioning of the ecosystem components.

Conclusion and Future Perspective

Nepal's biodiversity is a reflection of its unique geographic position and altitudinal and climatic variations. Decrease in snowfall and snow cover in the Himalayan region affects the Nomad groups to feed their livestock. Global warming had resulted in shifting of vegetation toward higher altitude, change in phenology, extinction of species, and behavioral change in the plants. A slight increase in the mean annual temperature of 1 °C is sufficient enough to bring substantial changes in the growth and regeneration capacity of many tree species. *Abies spectabilis* is better regenerating than *Betula utilis* in higher altitudes. The precious plant biodiversity of the mountain are changing rapidly and shifting upwards in response of increase in temperature. Endangered and endemic plant species are in a threat of disappearance due to adverse change in climatic parameters.

Hence, an appropriate measure for the mitigation of anthropogenic GHG causing climate change is recommended for minimizing the impact on plant diversity. Further researches on climate change and its impact on plants are necessary to assess the real impact on plants.

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Chapter 7
Impact of Climate Change on Mountain Flora and Vegetation in the Republic of Macedonia (Central Part of the Balkan Peninsula)

Andraž Čarni and Vlado Matevski

7.1 Introduction

The Republic of Macedonia is situated in the central part of the Balkan Peninsula (Fig. 7.1). Its geographical position is between 40°51′16″–42°22′21″N and 20°27′32″–23°02′12″E. It has borders with Serbia, Kosovo, Bulgaria, Greece, and Albania (Fig. 7.1). The area of the country is 25,713 km^2 and there are 2,022,547 inhabitants (in 2002). The average population density is 78.7 inhabitants per km^2 (Stojmilov 2011).

7.2 Geology and Relief

The territory of the Republic of Macedonia, as part of the Balkan Peninsula, is characterized by complex geotectonics, which have led to the development of diverse relief and complex geology as well as a huge variety of soil types. During the complex geotectonic evolution, the relief morphoplastic has changed several times.

In general, four geotectonic regions (units) are present on the territory of the Republic of Macedonia: West Macedonian region, Pelagonian massif, Vardar region, and Serbo–Macedonian massif (Jovanovski et al. 2012).

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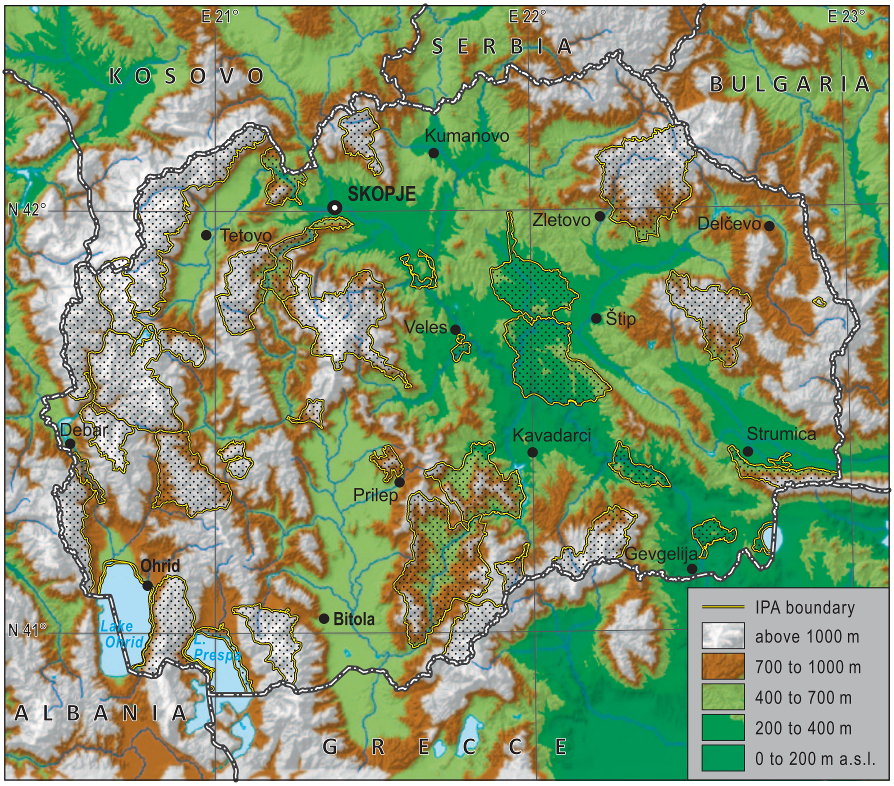

Fig. 7.1 Geographical map of the Republic of Macedonia with indication of *important plant areas* (IPA; after Melovski et al. 2010)

The West Macedonian region is a distinct geotectonic unit in the western part of Macedonia. Paleozoic and Triassic schists are most abundant in this region, while Jurassic, Cretaceous, and Paleocene rock formations and Neogene sediments are less present. The Pelagonian massif is a crystalline core with a continental type of Earth's crust that is built mostly of the oldest Precambrian formations. The Vardar region is a large and important lineament structure of the Balkan Peninsula that continues further on to Asia Minor. The intensive tectonic processes that took place at the end of the Jurassic period determined the shape of the structural forms of the Vardar region. The Serbo–Macedonian massif is an important continental structure of the eastern part of Macedonia, with a north–south orientation. It is built of metamorphic rocks of Precambrian, Riphean, Cambrian, and Paleozoic ages.

In the structure of relief, valleys and larger basins are spread over one third of the territory. The most characteristic are those along the river Vardar, such as the Polog, Skopje, Tikveš, and Gevgelija–Valandovo basins. These basins are connected with Žeden, Taor, and Demir Kapija gorges. The largest basin in Macedonia is Pelagonija basin (4000 km^2), located in the southwestern part of the country. In Western Macedonia, the most characteristic are Ohrid-Struga, Prespa, and Debar basins, while in eastern and southeastern Macedonia: Berovo, Pijanec, Kočani, Ovče pole basins, and the Strumica–Radoviš valley appear.

Traces of diluvial glacial relief and glacial cirques are preserved only in some mountains, mostly in Western Macedonia—Korab, Šar Planina, Bistra, Stogovo, Jakupica, and Galičica. Karst relief is present in the Paleozoic, Mesozoic, Paleogene, and Neogene limestones, so limestone masses are most represented on the mountains of Suva Gora, Žeden, Jakupica, Bistra, Galičica, and the higher parts of Šar Planina. The following karstic features can be found: cracks, coves, sinkholes, and karstic poljes, while caves and sinks are rare.

7.3 Climate

As a result of specific natural and geographical characteristics, the territory of Macedonia has two main types of climate—Mediterranean and continental. They cause the appearance of two specific periods of the year—a cold and wet winter, typical of a continental climate and a dry and hot summer, which corresponds to the Mediterranean climate. In higher mountain regions, the impact of a mountain climate can be observed, characterized by short fresh summers and a cold, moderately wet winter period, during which precipitation usually falls in the form of snow. Despite the proximity of the Aegean and Adriatic Seas, the influence of the Mediterranean climate does not penetrate deep into the territory of Macedonia, because the highest mountains rise in the western and southern part. The influence of the Aegean Sea can be recognized in the valley of the Vardar to Demir Kapija and less in the Skopje valley, as well as in the valleys of the rivers Strumica and Bregalnica. The influence of the Adriatic Sea can be recognized in Western Macedonia, in the valley of the river Drim. The continental influence penetrates from the north to the south and this climatic influence is most important in Macedonia.

The average air temperature of the country is 11.3 °C, the warmest towns are Valandovo (14.5 °C) and Gevgelija (14.3 °C). In regions with a mountain climate, average annual temperatures are as follows: Popova Šapka (4.7 °C), Lazaropole (6.8 °C), and Kruševo (8.2 °C). The mean annual precipitation on the territory of Macedonia is 683 mm. The largest amounts of rainfall were recorded in Mavrovi Anovi (1198 mm), while the driest part of Macedonia is Ovče Pole, where 490 mm of rainfall was registered (Filipovski et al. 1996).

7.4 Flora

In comparison with other European countries, Macedonia is characterized by high floristic diversity, with about 3300 species of high plants (about 3800 species, mosses included). This is a result of its central position in the Balkan Peninsula, as well as its geologic and tectonic history, climatic conditions, and other changes that have occurred in this part of the Balkan Peninsula, from the Tertiary to the present. Various floristic influences appear in the country, especially from the eastern and central Mediterranean, Asia Minor, Central Europe, boreal, and arctic areas of Eurasia (Matevski 2013).

The oldest in their genesis are Tertiary relicts, which have been preserved in certain refugial areas in the mountain belt or have migrated to lower regions where the climatic conditions were more favorable for their survival. Tertiary relicts that have found refugial areas in the higher mountain regions include *Pinus peuce* (Pelister, Nidže, Jablanica), *Pinus heldreichii* ssp. *leucodermis* (Šar Planina, Galičica, Nidže) and others. The Tertiary flora of the lowland belt has to a large extent disappeared, with only some relict species having been preserved in certain refugia, such as river gorges, where the influence of glaciation was much less pronounced (Košanin 1924; Micevski 1978a). Such is the case with two relict species of the tropical family *Gesneriaceae*: *Ramonda nathaliae* (preserved in the gorge of the Vardar river and its tributaries), *Ramonda serbica* (in the gorge of the Garska river, Radika, Crni Drim, Galičica), as well as *Aesculus hippocastanum* (gorge of the Crni Drim, Galičica, the upper part of the Treska river), and *Viola kosaninii* (Jakupica, Karadžica).

Boreal relicts in Macedonia are mainly distributed in coniferous forests—spruce, fir, and mountain heaths (*Picea excelsa, Listera cordata, Coralorhiza trifida, Parnassia palustris, Drosera rotundifolia,* and others).

Glacial relicts are found in the highest mountain regions, where they had refugial areas in moist and cold habitats, such as snow beds, alpine pastures, screes, etc., where the snow remains for a longer period (*Juncus trifidus, Aster alpinus, Ranunculus crenatus, Dryas octopetala, Salix reticulata, Salix retusa, Salix herbacea, Saxifraga aizoides, Saxifraga oppositifolia, Selaginella selaginoides, Diphasium alpinum,* etc.).

Xerothermic steppic relicts represent the remnants of steppe flora, which appeared at the end of the Tertiary (Pliocene) in certain parts of the Balkan Peninsula and found a natural refuge on the territory of Macedonia. The land connection between the southern part of the Balkan Peninsula and Asia Minor existed until the Pliocene. Steppic species have development centers in Asia Minor and Central Asia and arrived in this way. Evidence of this connection is the large number of common plant species, such as *Phelipaea boissieri, Capparis sicula, Morina persica, Astragalus parnassi, Convolvulus holosericeus, Kraseninnikovia ceratoides, Adonis vernalis, Comandra elegans, Asparagus tenuifolius,* etc.

The largest part of the recent flora of Macedonia derives from ancient Mediterranean flora, which was widespread in the Balkan Peninsula during the Tertiary. The main phytogeographic corridors by which the Mediterranean flora penetrated into the territory of Macedonia were the valleys of the Vardar and Drim rivers, through which a large number of species of Mediterranean and submediterranean floristic elements migrated (*Periploca graeca, Quercus coccifera, Punica granatum, Phyllirea latifolia, Arbutus andrachne, Salvia officinalis, Hyssopus officinalis, Convolvulus elegantissimus, Quercus trojana, Euphorbia characias* ssp. *wulfenii,* etc.).

A number of Balkan and local endemic species have special significance in the flora of Macedonia. Around 120 local (Macedonian) endemic species can be found in Macedonia. The most important centers of endemism are considered to be the high mountains (Šar Planina, Korab, Galičica, Jakupica, and Bistra) and river gorges (Vardar, Treska, Crna Reka, and Babuna) as well as some parts of the lowland belt (Mariovo, around Prilep, and steppic area in the central part of Macedonia).

Alpine endemic species are the most numerous so that almost every mountain in Macedonia has its local endemics (Micevski and Matevski 1987). The richest in endemic species are Galičica (*Crocus cvijicii, Centaurea galicicae, Centaurea soskae, Centaurea tomorosii, Laserpitium ochridanum, Astragalus mayeri, Edraianthus horvatii, Festuca galicicae, Helichrysum zivojinii, Micromeria kosaninii,* etc.), Šar Planina (*Crocus scardicus, Verbascum scardicolum, Potentilla doerfleri, Sempervivum kosaninii, Viola schariensis,* etc.), Jakupica (*Pedicularis ferdinandi, Colchicum macedonicum, Sempervivum macedonicum, Viola bornmuelleri, Dianthus jakupicensis*), Pelister (*Crocus pelistericus, Dianthus myrtinervius, Sempervivum octopodes, Alchemilla peristerica*), and Nidže-Kajmakčalan (*Silene horvatii, Dianthus kajmatzalanicus, Peucedanum lavrentiadis, Viola doerfleri*).

Some of the endemic species are of Tertiary *Thymus oehmianus, Viola kosaninii, Crocus cvijicii, Crocus scardicus, Colchicum macedonicum, Narthecium scardicum,* etc.). The second group represents neoendemics, such as *Thymus karadzicensis*, various species of the genus *Centaurea* (*Centaurea skopjensis, Centaurea kavadarensis,* etc.), *Dianthus* (*Dianthus macedonicus, Dianthus ochridanus*), which have limited distribution on the territory of Macedonia, which is explained by their evolutionary youth and lack of time to expand.

7.5 History of Floristic Research

The first person to have published data on the flora of Macedonia was August Grisebach (1814–1879), director of the botanical garden and professor at Göttingen University. He dealt with flora and especially phytogeography. He described about 30 new taxa for science from the territory of Macedonia (Grisebach 1843–1844). Mention should also be made of the well-known Swiss botanist, Edmond Boisser, and a whole group of Czech botanists: Formánek, Velenovský, Čelakovský, Vandas, Rohlena, Dostal, etc., Ignac Dörffer from the Botanical Garden and Museum in Vienna, Richard von Wettstein, professor of plant systematics from Prague and Vienna, Arpand Degen from Pest (Hungary), and Dimitrie Grecescu from Bukurest also carried out investigations in the country.

At the beginning of the twentieth century, there were enough floristic data for the synthetic phase to begin. One of the most important publications, Die Vegetationsverhältnisse von Balkanländer (1909), was prepared by Lujo Adamović (1864–1935) based on an ecological-physiognomical approach in the investigation of vegetation. He presented a horizontal and vertical zonation of vegetation in the Balkan Peninsula and the genesis and historical development of vegetation. He also dealt with flora, especially endemic and relict species. A professor of botany at Belgrade University, Nedeljko Košanin (1878–1934), dealt above all with endemic and relict flora. He was of the opinion that endemic taxa exist on every Macedonian mountain. He thought that these species also had a limited distribution pattern during the Tertiary, since these mountains are old and there were no geologic phenomena that would affect them. Mention should also be made of Fridrich Bornmüller (1862–1948), who worked on the territory of Macedonia during WW1. He published a series of papers about the flora of Macedonia. The most important work dealing with the synthesis of flora of the region was published by the Austrian botanist, August Hayek (1871–1928), who prepared a determination key for flora of the southern Balkans (Hayek 1924–1927, 1928–1931, 1933). The last in this era was William Bertand Turrill (1890–1961), who prepared and described the floristic and phytogeographic peculiarities of the Balkans (Turill 1929).

Some researchers that also focused on vegetation after this synthetic phase should be mentioned. Ivo Horvat (1897–1963) introduced the standard Central European method into the region. He visited the region in the period from 1933 to 1938 and later published several articles about the vegetation (Horvat 1934, 1935, 1936a, 1937, 1938). Two Macedonian researchers deserve mention: Hans Em (1983–1992), who began to investigate with I. Horvat and later dealt primarily with forest vegetation of the region and Kiril Micevski (1926–2002), who dealt with flora and nonforest vegetation (Matevski 2009).

7.6 Climatic Division

The main idea of the regionalization prepared by Filipovski and collaborators (1996) was that climazonal vegetation reflects the climatic condition of the area. At the same time, it must be taken into consideration that zonal soil types appear in each region, with their own successional series.

The appearance of vegetation is induced by a whole complex of natural and anthropogenic factors, as well as the historical development of vegetation in the area. However, factors that influence vegetation development are of different importance. Macroclimate is decisive for the appearance of zonal vegetation, which builds the potential natural vegetation of the region (climax), other more localized factors are important for other types of vegetation, e.g., the vegetation along rivers is maintained by the course of the river (paraclimax) and the anthropogenic factor is decisive for the formation of a vast range of anthropogenic vegetation.

In general, climatic regions are very broad in a horizontal direction but quite narrow in their vertical distribution. In the horizontal direction of the region, the most pronounced is the gradient of diminishing influence of the maritime and increasing influence of continental climate, i.e., the distance from the Aegean Sea (Ćušterevska et al. 2012). However, the main division is in a vertical direction, whereby several different climatic regions with special character can be found. (Table 7.1).

If it is recognized that macroclimatic changes result in changes of zonal vegetation, the distribution of zonal vegetation can be used as an indicator of climatic region. At the same time, it must be taken into consideration that each species and also vegetation community has its own climatic amplitude. This means that the climate is not homogeneous within one region but possesses a specific amplitude, so climatic and vegetation (sub) types can also be detected.

Table 7.1 Division of Macedonia to eight regions based on climate, vegetation, and soil. (After Filipovski et al. 1996)

Number	Name of region	Altitude	Mean annual temperature	Percentage of territory	Dominant species
1	Submediterranean (modified Mediterranean)	50–500	14.2		*Quercus coccifera*
2	Continental submediterranean	100–600	12.7	34.9 regions 1 and 2	*Carpinus orientalis*
3	Warm continental	600–900	10.9	27.4	*Quecus frainetto*
4	Cool continental	900–1100	8.8	13.3	*Quercus petraea*
5	Submontane-continental	1100–1300	8.0	9.7	*Fagus sylvatica*
6	Montane continental	1300–1650	6.4	10.4	*Fagus sylvatica*
7	Subalpine mountain	1650–2250	3.5	3.8	*Fagus sylvatica*
8	Alpine mountain	2250–2764	−0.4	0.5	Grasslands

According to Filipovski et al. (1996), Macedonia can be divided into eight regions based on climate, vegetation, and soil (Table 7.1). It comprises the following regions:

1. Submediterranean (modified Mediterranean) region
   This region is dominated by *Quercus coccifera* and *Carpinus orientalis*. *Q. coccifera* has the northern limit of its distribution here (Oberdorfer 1948). The area is in the southern part of Macedonia and the influence of the Aegean Sea is quite pronounced. There is a mixture of evergreen and deciduous thermophilic and xerophilic plant species. As degradation, there is the formation of shrub species called pseudomaquis. This is the transition from evergreen maquis towards more continental scrub communities called šibljak (Bergmeier and Dimopoulos 2008). In the case of further degradation, there is also garrigue dominated by *Cistus incanus* and early spring therophitic grasslands (*Romulion;* Čarni et al. 2010, 2014). Some characteristic species: *Quercus coccifera, Q. pubescens, Carpinus orinetalis, Phyllirea latifolia, Pistacia terebinthus*.
2. Continental-submediterranean region
   This region is dominated by *Quercus pubescens–Carpinus orientalis*. The region is widely distributed all over the country. The vegetation is the most xerophytic in the research area; the influence of the continental climate is well pronounced. Forests are fairly rare in this area. It was already settled several thousand years ago and it was converted to agricultural land (Bergmeier and Dimopoulos 2008; Čarni et al. 2009). Some characteristic species: *Quercus pubescens, Carpinus orientalis, Fraxinus ornus, Acer monspessulanum, Cornus mas, Ostrya carpinifolia*.

3. Warm continental region
   This is the typical vegetation of the large basins in the western part of the country. This region is mainly flat at the bottom of basins or on the lower part of mountains. The dominant species in these forests are *Quercus frainetto* and *Q. cerris*. Stands are dominated by *Q. frainetto* but *Q. cerris* is nearly always present. There are no endemic species in this area; the dry period eliminates mesophilous endemic species and winter frost eliminates the thermophilous elements. At the same time, these areas are agricultural, with well-developed anthropogenous vegetation. (Em 1964a; Matvejeva 1982; Matevski et al. 2011) Some characteristic species: *Q. frainetto, Q. cerris, Pyrus pyraster,* and *Malus florentina.*
4. Cool continental region
   There are no more flat surfaces from this region on, only more or less steep slopes. This is a relatively narrow region of about 200 m between the warm continental region dominated by *Q. frainetto* and *Q. cerris* and the submontane continental region dominated by beech (*Fagus sylvatica*). These forests are the last extension of thermophilous deciduous forest in the altitudinal range. Forests are dominated by *Quercus cerris* in the lower part and by *Quercus petraea* in the upper part of the region. Because this region is steep, forests have been mainly converted to pastures, rarely to arable land. (Em 1964b; Matevski et al. 2011) Some characteristic species: *Quercus petraea, Fraxinus ornus, Sorbus torminalis, Acer campestre, Corylus avellana*.
5. Submontane continental region
   Submontane beech forests (*Festuco heteropyllae-Fagetum*) can be found in this region. The region extends about 200 m in the vertical direction and forms a vegetation belt at altitudes from 1000 to 1200 m, although in warmer sites it can reach up to 1500 m. (Rizovski and Džekov 1990; Matevski et al. 2011; Marinšek et al. 2013) Beech (*Fagus sylvatica*) shows some genetic variability in comparison to beech in the western part of the Balkans and other parts of Europe. Beech in southeastern Europe has been treated as *Fagus moesica* in the past but new findings show that it cannot be treated as an independent species, although it nevertheless shows a certain genetic peculiarity (Brus 2010). This region seems to be an area in which lowland vegetation gradually disappears and (sub)alpine vegetation gradually appears. Here, we can still find the lowland dry grassland communities of *Saturejo-Thymion* (*Astragalo-Potentilletalia, Festuco-Brometea)* on carbonate substrate (Micevski 1970; Matevski et al. 2015). Dry grassland of the alliance *Armerio-Potentillion* can be found on noncarbonate bedrock (Micevski 1978b). On deeper soil, meadows are found that are classified within the endemic alliance *Rumicion thyrsiflori* (*Arrhenathereta, Molino-Arrhenatheretea*). (Micevski 1994; Melovski and Matevski 2008). Some characteristic species: *Fagus sylvatica, Carpinus betulus, Prunus avium, Corylus avellana, Quercus petraea*.
6. Montane continental region
   The montane region appears from 1300 to 1650 m. No dry season can be detected in the region. Extremely high temperatures are mitigated by altitude and there are often fogs. Climatic conditions in this region are favorable for beech, which, as a subatlantic species, appears in regions with humid and cool climate. Beech

and mixed beech–fir forest can be found; beech is mixed with *Abies alba* in the northern part of the country and with *Abies borisii-regis* in the southern part. The following associations can be found in the region: *Calamintho-Fagetum, Bruckentalio-Myrtillo-Fagetum* and *Abieti borisii-regis-Fagetum, Fago-Abietetum meridionale*. (Em 1974; Em 1975; Matevski et al. 2011). Some characteristic species: *Fagus sylvatica, Acer platanoides, Acer pseudoplatanus, Ulmus scabra, Abies borisii-regis, A. alba*.

7. Subalpine mountain region
   The area extends over a relatively wide range of 600 m of altitude, between 1650 and 2250 m. The area is fairly small, since not many mountains reach such an altitude. It is the highest belt with forest vegetation, where forest vegetation meets its limiting climatic conditions. The forests are low, often in shrubby form and deformed (sabre trees). The area has been deforested in the past in order to obtain suitable areas for secondary subalpine grasslands. The timberline has, thus, been lowered by 300–400 m. Only a smaller part of the area is covered by forest today, the major part is secondary pastures or heaths. (Vassilev et al. 2011) These forests can be reconstructed on the basis of fragments or remnants found on some steep slopes unfavorable for pastures. The timberline can be built of *Fagus sylvatica, Abies alba, Picea abies, Pinus peuce, Pinus heldreichii, Pinus sylvestis,* and *Pinus mugo*.
   Subalpine beech forests can be found all over Macedonia. They are linked to montane beech forests but they are different in the form of beech (sabre trees) and their floristic composition is also different (Em 1961; Rizovski and Džekov 1990; Matevski et al. 2011). Subalpine forests dominated by *Pinus peuce* appear on silicate bedrock on rocky soils (Pelister). Stands of *Pinus peuce* have also spread from these into secondary stands on sites of montane and even submontane beech forest. It is fast expansion. Subalpine *Pinus peuce* forest shows a similar floristic composition as subalpine beech forest (Em 1962). Forests of *Pinus heldreichii* are practically destroyed and only some remnants can be found on Galičica, over limestone bedrock (Horvat et al. 1974). *Abies alba* forests (they are sometimes mixed with *Picea abies*) appear up to 1800 m. They are found on sites with high air and soil humidity over carbonate and noncarbonate bedrock. In some cases, these forests are in contact with subalpine grasslands but Em (1974) thinks that subalpine beech forests also existed above fir forests that have been destroyed and, in such cases, *Abies alba* now builds the timberline (Em 1974). *Picea abies* forest can be found on small areas on Šar Planina mountain. It can appear as pure *Picea* forest or mixed with *A. alba* at altitudes from 1700 to 2000 m on humid and cool sites (Em 1986). On Nidže mountain, timberline built of *Pinus sylvestis* can be found. Both *Pinus sylvestis* and *Pinus nigra* can be found in the area but *Pinus nigra* is found on warmer sites. *Pinus sylvestis* is sometimes mixed with *Pinus peuce* in the area (Em 1981). Communities of *Pinus mugo* are rare in the country and can appear at the highest altitudes of the subalpine belt (Šar Planina and Jakupica) up to 2500 m and they protect the soil against erosion. These communities can be found on limestone and on noncarbonate bedrock (Em 1962; Šibík et al. 2010).

8. Alpine mountain region
   Forest vegetation cannot be found in this region and only herb species can survive the severe conditions. This vegetation can be found only on small areas, since only a few mountains reach this altitude (Kožuf, Nidže, Pelister, Dešat, Korab, Šar Planina, and Jakupica).
   The vegetation is adapted to severe conditions: thin soils, high water permeability, strong winds, accumulation of snow, steep slopes, etc. Depending on site conditions: aspect, inclination, depth of soil layer, strength of wind, duration of snow cover and human impact, various vegetation types appear.

The following vegetation types can be found on Macedonian mountains:

Grasslands of the class of alpine and subalpine calcareous swards *Elyno-Seslerietea* and the Balkan order *Onobrychido-Seslerietalia* can be found on carbonate bedrock. These grasslands are further divided into two groups: *Edvaiantho-Seslerion* in the alpine vegetation belt and *Onobrychido-Festucion* (syn. *Seslerion nitidae*) in the subalpine vegetation belt. The vegetation of *Onobychido-Festucion* appears at lower altitudes, on warm and protected sites. The soil horizons are deep and the habitat is covered by snow during winter. The tussocks of grasses are relatively dense and communities build fairly closed vegetation. This vegetation can also appear at lower altitudes on sites of subalpine beech forests. The other vegetation type is *Edvaiantho-Seslerion* (syn. *Anthyllido-Seslerion*). This vegetation is visually very different from the former one. The stands are dominated by sedges, low grasses, chamaephytic species, and many small herbs. These communities are adapted to extreme site conditions, low temperatures, and high day–night fluctuations of temperature. These communities are strongly influenced by wind, which has a mechanical and physiological influence on the communities. It removes the snow during winter and dries out the sites, so the vegetation is xerophytic despite precipitation (Horvat 1936b, Horvat 1960; Micevski 1994; Karagiannakidou et al. 2001; Redžić 2011a, 2011b).

Acidophilous grasslands of the alpine and subalpine belts are classified within *Caricetea curvulae*. These grasslands in the Balkan Peninsula belong to the endemic order *Seslerietalia comosae*.

Communities on deep acidic soils in wind-sheltered habitats are classified within *Poion violaceae*. These communities develop on deep soils in sheltered habitats. The stands are dense and fairly uniform. In the case of too intensive grazing, these communities are converted to *Potentillo ternatae-Nardion*. (Horvat 1960)

Grasslands on deep acidic soils in wind-exposed habitats of the Balkan Peninsula are assigned to *Seslerion comosae*. These communities appear on ridges that are exposed to wind, where the bedrock is without carbonates (Horvat 1935; Redžić 2011b).

Within *Caricetea curvulae*, the order of alpine acidophilous species-rich grassland *Festucetalia spadiceae* with the alliance *Knautio-Patzkeion* can also be distinguished. This alliance comprises tussock grasslands on decalcified deep soils at high altitudes of the Balkan Peninsula. The soil is leached and therefore acidic, which enables the development of these acidophilous communities (Čarni and Mucina 2015).

Under human impact, secondary mat-grass swards on nutrient-poor soils appear, which can be classified within *Nardetea strictae* and *Nardetalia strictae*. These oligothrophic mat-grass swards of mountains of the south-central Balkan Peninsula are further classified within *Potentillo ternatae-Nardion*. They cover large areas on both carbonate and noncarbonate bedrock but on carbonate bedrock appear only on sites with deep soil horizons. These communities are fairly similar all over the country, being differentiated according to the community that they replace. Mat-grass swards can appear on all sites except those that are exposed to strong wind (Horvat 1935; Velev and Apostolova 2009).

Chasmophytic vegetation appearing in crevices and on the surfaces of rocky cliffs and walls is classified within *Asplenietea trichomanis*. Because of the extreme ecological conditions, the vegetation is species poor, with low cover. However, specializied species nevertheless find their ecological niche in such conditions.

Chasmophytic vegetation of carbonate crevices in high mountains of the southern Balkans is further classified within *Potentilletalia speciosae*, and those of the alpine belt within *Ramondion nataliae*. The vegetation of these habitats is very diverse and many paleoendemic species can be found there.

The crevice vegetation of siliceous rocks is classified within *Androsacetalia vandelii* and the alliance *Silenion lerchenfeldianae*. The vegetation on noncarbonate bedrock is quite different from the vegetation over carbonate bedrock. Many breaks and fractures can be found on carbonate bedrock, which enable the development of chasmophytic vegetation; such sites appear on silicate bedrock only sporadically. As a consequence, the vegetation is not so widely distributed as the vegetation on carbonate bedrock. Moreover, it has to be taken into consideration that more endemic species appear on carbonate bedrock (Horvat et al. 1937; Simon 1958; Horvat 1960; Mucina et al. 1990; Micevski 1994; Dimopoulos et al. 1997; Ewald 2003).

Screes develop below steep cliffs and walls that are the result of tectonic movements. Under the influence of cosmic and atmospheric factors, cliffs decay and the material accumulates below them. The deeper scree is composed of small rock elements that move at every touch but below the scree can be found large rock blocks. Vegetation of scree habitats and pebble alluvia is classified within *Drypetea spinosae* and *Arabidetalia flavescentis*. Calcareous scree vegetation of montane to subalpine belts is classified within *Silenion marginatae* (Horvat et al. 1974; Dimopoulos et al. 1997; Valachovič et al. 1997; Dimopoulos 2011).

In comparison with dry scree vegetation of *Drypetea spinosae*, the vegetation of snow-beds of *Salicetea herbaceae* is much more moisture tolerant. These communities survive a very humid environment and long snow cover, which often lasts until the end of July, so vegetation develops at the beginning of August. This vegetation is classified within *Arabidetalia caeruleae* and *Arabidion caeruleae* on carbonate and *Salicetalia herbaceae* and *Salicion herbaceae* on silicate bedrock (Horvat 1960; Mucina et al. 1990).

The vegetation around small springs develops above all on silicate bedrock. The floristic composition is a result of the permanent flow of water, which maintains a relatively stable temperature of the site. It is classified within the class of vegetation of cold springs *Montio-Cardaminetea* and order *Montio-Cardaminetalia,* containing vegetation of cold oligothrophic springs. This vegetation in Macedonia is classified within the alliance *Pinguiculo balcanicae–Cardaminion acris* (Hájek et al. 2005; Čarni and Matevski 2010).

The class *Mulgedio-Aconitetea* encompasses shrub and tall herb vegetation of high altitudes growing on moist and fertile soils that are under the influence of percolation water. It can be further classified within the order *Adenostyletalia*. Two alliances can be distinguished within this order: *Cirsion appendiculati* and *Geion coccinei.* The first includes vegetation that develops only around springs and along streams and rivers. The other can be found on sites that are soaked with water for extended periods during spring, when the snow melts. Communities of tall-herb and fern-rich communities on acidic to leached carbonate soils *Calamagrostietalia* within the alliance *Calamagrostion villosae* can also be found. Nitrophilous vegetation that appears around stables for animals that are maintained in the mountains can also be classified within this group. It is classified within *Senecioni rupestris-Rumicetalia alpini* and *Rumicion alpini* (Horvat et al. 1937, Horvat 1960; Micevski 1994; Michl et al. 2010; Čarni et al. 2010).

Fen vegetation is widespread on all Macedonian mountains but fragmentarily, in places where small permanent springs soak sites and enable the development of moor vegetation. Fens appear on both silicate and carbonate bedrock. On silicate bedrock, they are classified within the class of vegetation of transitional mires, fens, and bog hollows *Scheuchzerio palustris-Caricetea fuscae*. Further fens and mires and fens developing on mesotrophic and oligo-mesotrophic peats and peaty mineral soils are classified within *Caricetalia fuscae* and *Caricion canescenti-fuscae.* The small-sedge rich-fen vegetation of oligo-mesotrophic calcareous peaty soils in springs and shallow fens is classified within the order *Caricetalia davallianae* and *Caricion davalianae*—small-sedge rich-fen vegetation of calcareous oligotrophic flushes (Horvat 1960; Hájek et al. 2005; Hájková et al. 2006).

Alpine heaths are built of chamaepytic shrubs that are accompanied by species from alpine grasslands. These communities can appear on large areas over silicate bedrock but are much more sporadic over carbonate bedrock. They also appear on areas of subalpine forests deforested in the past. Arctic-boreal tundra scrub and relict (sub)alpine acidophilous dwarf heath are classified within *Loiseleurio-Vaccinietea* and *Rhododendro ferruginei-Vaccinietalia*. Ericoid subalpine chionophilous dwarf scrub heaths of the southern Balkans are further classified within *Bruckenthalion spiculifoliae* (Zupančič 1992).

Subalpine and alpine dwarf heath on rocky calcareous soils is classified within *Rhododendro hirsuti-Ericetea carneae* and *Rhododendro hirsuti-Ericetalia carneae*. In Macedonia, this vegetation type is classified within *Daphno-Genistion radiatae* (Ranđelović and Redžepi 1980).

7.7 Important Plant Areas (IPA)

In order to implement effective protection and conservation of populations of wild species, an initiative has been undertaken to indicate IPA. IPA are defined as areas with natural or seminatural habitats that are extremely rich in plant diversity (rare, relict, and endemic plant species and/or plant communities that have a high botanical value, or are in any way threatened). The main objective is to identify and protect priority areas for the conservation of plant species and plant communities, using established international and regional criteria, such as the presence of international, regional, and locally important species, botanical richness, and the presence of endangered habitats. Based on the above criteria, 42 IPA on the territory of Macedonia were selected, of which 12 are transborder (Melovski et al. 2010). Some IPAs cover large areas (mountain ranges), while some of them have a relatively small area (these are usually areas with a high concentration of plant species and habitats represented on small surfaces). The major part of the IPA (26) encompass areas that are in the region above an altitude of 1000 m. This includes almost all mountain ranges in Macedonia, as well as botanically significant sites that are located at lower altitudes, at the foot of mountain massifs (Alšar, Baba Sač, Belasica, Bistra, Buković-Straža, Galičica, Ilinska Planina, Jablanica, Jakupica, Kožuf-Dudica, Korab, Dešat, Barbaros, Mariovo, Mavrovo, Nidže, Judovi Livadi, Pelister, Plačkovica, Markovi Kuli-Treskavec, Žeden, Skopska Crna Gora, Stogovo, and Šar Planina). The areas are shown on a map (Fig. 7.1).

7.8 Climate Change in the Recent Period

An analysis of climatic changes in the recent period and foreseen climatic scenarios have been published in the Third Communication on Climate Change (Zdraveva 2014) and in the climate change scenarios for Macedonia prepared by the Hydrometeorological Service of the Ministry of Agriculture, Forestry and Water Economy (Karanfilovski 2012).

Data provided by the Hydrometeorological Institute show trends of a slight increase in average annual temperatures for the period 1971–2000 and 1981–2010 compared to the 1961–1990 period (Fig. 7.2). A positive trend of temperature in-

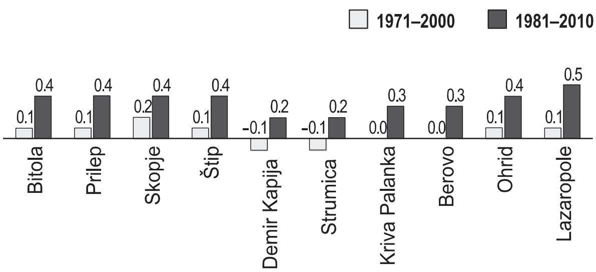

Fig. 7.2 Average air temperature. Deviation of the 30-year average in two periods, 1971–2000 and 1981–2010, compared with the period 1961–1990. (Source: Hydrometeorological Service in Zdraveva 2014)

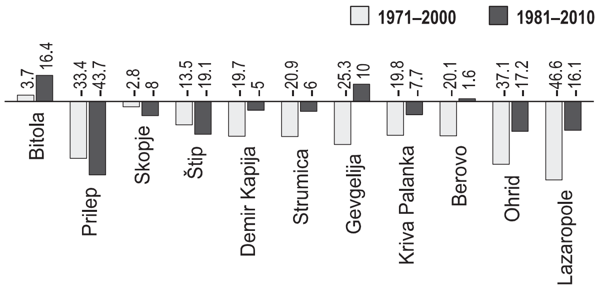

Fig. 7.3 Total average precipitation. Deviation in the 30-year average in two periods (1971–2000 and 1981–2010) from the 1961 to 1990 period. (Source: Hydrometeorological Service in Zdraveva 2014)

crease was registered for almost all studied regions. The smallest change can be seen in areas under the influence of the Mediterranean climate, such as Demir Kapija and Strumica (southern part of the country: first climatic region) and the largest in Lazaropole (1300 m)

The amount of precipitation in the last 30 years has dropped significantly for most regions in Macedonia compared to the period 1961–1990. The most significant changes (negative difference) were observed in mountain regions (Fig. 7.3).

7.9 Climate Change in the Future

Climate changes indicate statistically significant changes in average climatic parameters over time. There have been numerous studies dealing with this topic in the world: climate warming is clearly recognizable, the average temperature of air and oceans is increasing, snow is melting, glaciers and ice on the poles is diminishing and there is a rise of sea levels. There has been a linear trend of increasing average air temperature in the period 1906–2005, of 0.74 °C. On a time scale of 50 years, the trend is even more worrying; there has been an increase of 0.13 °C per decade in the period 1956–2005 (Karanfilovski 2012). Global warming is to a large extent a result of human activities, which substantially raise the atmospheric concentration of greenhouse gasses. It can cause adverse effects on natural ecosystems. Since humanity is aware of this danger and wants to prevent or at least mitigate the adverse effects of global warming on the environment and humanity, the United Nations adopted the Framework Convention on Climate Change in 1992. The Republic of Macedonia ratified this convention in 1997 and prepared three national communications on climate change that deal with global warming and measures to mitigate its effect. The data in this chapter were drawn from those reports (Azievska 2008; Zdraveva 2014) and represent the basis of our evaluation.

The prediction was prepared by Karanfilovski (2012). The study of global warming is based on a model that is intended to present future warming scenarios, based

Table 7.2 Predicted changes in air temperature for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

Season	Winter				Spring				Summer				Autumn				Annual			
Scenario:	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100
high	1.1	2.4	3.8	5.0	1.4	3.0	4.6	6.2	2.4	4.8	7.9	10.6	1.5	3.0	5.0	6.7	1.6	3.3	5.3	7.2
medium high	0.9	1.9	3.0	3.9	1.1	2.4	3.6	4.8	1.9	3.8	6.2	8.2	1.2	2.4	3.9	5.2	1.3	2.6	4.2	5.5
medium	0.8	1.5	2.2	2.7	1.0	1.8	2.7	3.3	1.7	3.0	4.6	5.8	1.1	1.9	3.0	3.7	1.2	2.0	3.1	3.9
medium low	0.7	1.0	1.5	1.7	0.9	1.3	1.9	2.1	1.6	2.1	3.4	3.9	1.0	1.3	2.2	2.5	1.1	1.4	2.2	2.5
low	0.5	0.8	1.1	1.1	0.7	0.9	1.4	1.4	1.2	1.5	2.4	2.7	0.7	1.0	1.6	1.8	0.8	1.0	1.6	1.7

Table 7.3 Predicted changes in the quantity of precipitation (%). (After Karanfilovski 2012)

Season	Winter				Spring				Summer				Autumn				Annual			
Scenario:	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100	2025	2050	2075	2100
low	-1	-3	-2	-1	-2	-5	-7	-9	-4	-12	-29	-36	-1	-5	-8	-9	-2	-6	-8	-8
medium low	-1	-4	-3	-2	-2	-6	-10	-12	-6	-15	-38	-47	-1	-7	-10	-13	-3	-8	-10	-12
medium	-3	-6	-7	-9	-3	-8	-13	-17	-13	-25	-46	-57	-2	-9	-14	-20	-4	-10	-15	-19
medium high	-4	-8	-11	-16	-4	-9	-17	-23	-20	-38	-54	-66	-4	-11	-21	-27	-5	-11	-21	-27
high	-5	-10	-14	-20	-5	-12	-21	-29	-25	-48	-68	-80	-4	-14	-25	-34	-6	-14	-25	-33

on natural factors (solar radiation, water cycle process, etc.), emission of green house gases, and prediction of future economic, technological, demographic, and sociological development.

During the modeling, several scenarios were constructed. Initially, four families of scenarios were built, designated A1, A2, B1, and B2. These scenarios were then divided into subfamilies, e.g., the A1 family was divided into three subfamilies on the basis of the intensity and manner of use of energy resources, designated A1FI, A1B, and A1T. Several models were also used, e.g., Asian Pacific Integrated Model (AIM). In the process, several scenarios of values for temperature and precipitation changes were produced: for each of the 12 months, for seasons: winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), and autumn (September, October, and November), as well as an average annual value.

An assessment of air temperature and precipitation changes was made for the period 2025–2100 on the basis of data from the period 1961 to 1990, which was used as reference point. Since the scenarios have a spatial resolution of 2.5° × 2.5°, only two points appear on the territory of Macedonia and we have chosen only the one that is valid for almost the whole country, indicated as A (41.25°N; 23.75°E), with a central point near Demir Hisar.

The predicted data are presented in the tables (Tables 7.2 and 7.3) according to the different scenarios for the years 2025, 2050, 2075, and 2100 (the year indicates the center of the period predicted):

- High (absolute maximum values, corresponding to the A1FI-MI scenario)
- Medium high (average maximum values)
- Medium (average mean values for the three values of climate sensitivity, very close to the A1B-AIM scenario)
- Medium low (average minimum values)
- Low (absolute minimum values, corresponding to the B1-IMA scenario).

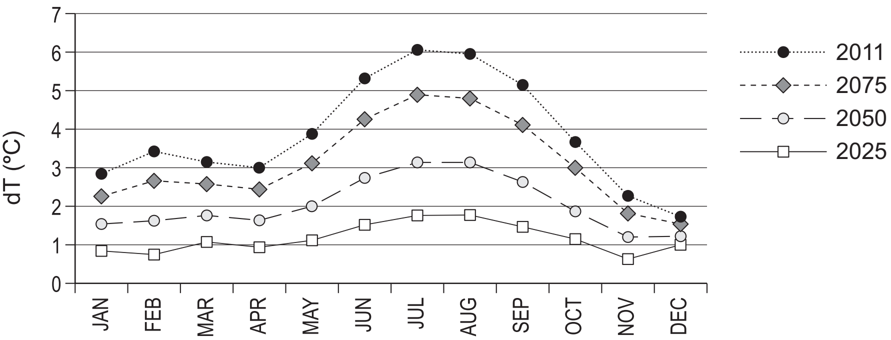

Fig 7.4 Annual course of medium predicted air temperature changes for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

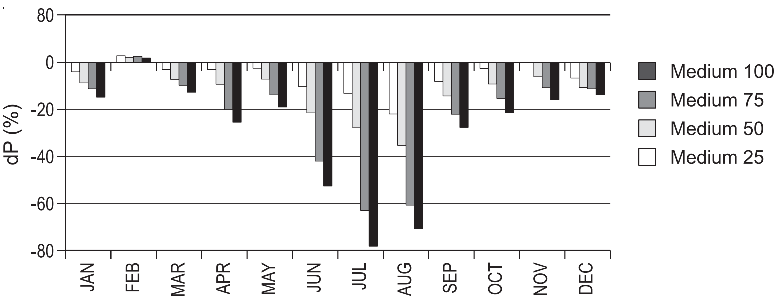

Fig. 7.5 Annual course of the medium predicted precipitation changes for 2025, 2050, 2075, and 2100. (After Karanfilovski 2012)

The result shows that all temperatures are positive and that warming will continue in the period 2025–2100 (Table 7.2). There will be warming during the whole period. Summers in particular will get warmer and warmer, while the rise of temperature will be less significant during the winter months. There will be two peaks of changes, a large one in July and a less pronounced one in February. The changes will be at a minimum during April and December. The minimum change in April and increase in February will equalize the temperature during spring (Fig. 7.4).

A decrease of precipitation is foreseen in the period 2025–2100 (Table 7.3). The decrease will happen in all seasons; the only increase will be in February. The intensity of change will be greatest in the warm part of the year, in July and August. The intensity of change may reach 100 %, meaning that those months will probably be without precipitation. In the cold period of the year, a decrease of precipitation up to 40 % is predicted (Fig. 7.5).

7.10 Impact of Climate Change on Flora and Vegetation

Global changes have an impact on various environmental components. Biodiversity is one of the most dynamic and susceptible parts of the environment and is constantly subject to the impact of global changes. It reacts to the changes with its own adaptive capacity. Flora and vegetation can adapt to global changes; it can also migrate to other areas with more propitious site conditions, or new communities can be formed to adapt to new environmental conditions.

Since Macedonia is a relatively small, mountainous country, a minor change in latitudinal zonation can be expected, and only in the lowland region, where changes of influence of both maritime and continental climates can appear. In other parts of Macedonia, vertical zonation can be expected and changes in this direction are foreseen.

Refugial centers are greatly at risk (Em 1985, Brajanovska 2010). They are very important for the biodiversity of Macedonia due to the extraordinary species richness, especially with endemic and relict species. In these habitats, e.g., gorges or canyons, special microclimatic conditions can be found that are not directly influenced by macroclimatic conditions. Refugia are characterized by specific ecological conditions, such as a temperature regime without severe extremes, higher air and soil humidity during the dry season, etc. Species found shelter in these habitats during climate changes in the past.

The Second National Communication to the Convention on Climatic Change Sector Biodiversity (Matevski 2008) and the Third National Communication to UNFCC Sector Biodiversity (Melovski et al. 2013) provide the basis for the assessment.

Global climatic changes can have various impacts on a regional level, with different changes of temperature and precipitation in different regions. For certain regions, especially in the mountains, the temperature regime could be the more important factor causing disturbances and changes of composition of ecosystems, while other ecosystems are more sensitive to changes of precipitation, i.e., available humidity.

Considerable latitudinal movement of plant and animal species in a south–north direction is likely to be significant only in the lowland submediterranean region. Vegetation in the lowland submediterranean region (i.e., modified Mediterranean) is dominated by *Quercus coccifera* and *Carpinus orientalis*.

The predicted distribution of *Q. coccifera* has been modeled for the period to 2100 based on the A1B scenario (Fig. 7.6). This scenario is fairly pessimistic and foresees a market-oriented economy and fairly rapid economic growth. In this prediction, the world's population will grow until 2050 and then decline. Kermes oak (*Q. coccifera*) thrives at present in the southeast part of Macedonia, in the area along the Vardar river below the gorge of Demir Kapija, which stops the maritime influence from penetrating further into the Balkan Peninsula. The community is dominated by kermes oak, oriental hop-hornbeam (*Carpinus orientalis*) and pubescent oak (*Q. pubescens*), which build so-called pseudomaquis, a mixture of deciduous and evergreen species. The modeled current distribution and predictions

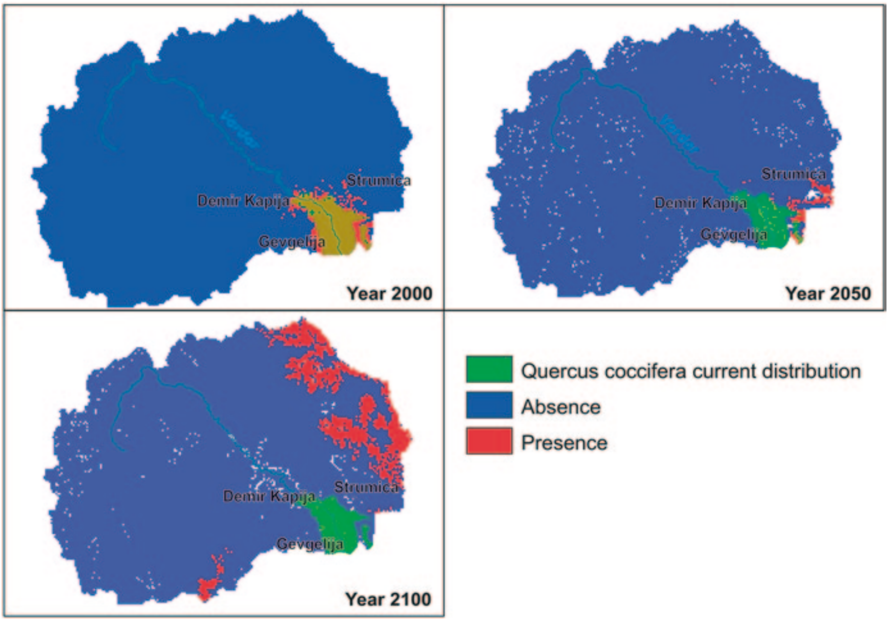

Fig. 7.6 Predicted distribution of *Quercus coccifera* for the period to 2100. (After Melovski et al. 2013)

are shown in Fig. 7.6. A shift towards the east of the country in the Strumica valley can be expected in 2050. A further shift towards the eastern part of the country is expected in 2010 (Osogovo, Plačkovica, etc.) It can be seen that the area of distribution will enlarge in the coming period.

The main changes will occur in the vertical distribution pattern. Major dislocation of vertical regions will appear, as well as a certain redistribution of species and ecosystems along the gradient. The size of the damage and species loss will depend on the rate of climate change, since changes of species distribution depend on their adaptation capacities and mobility.

Beech forests will extend their range towards the upper montane and subalpine belts. The reasons for such an expansion are not only climatic but also the abandonment of grazing in the country. Beech forests will reoccupy their natural stands in the area of subalpine pastures. Some problems in afforestation might be caused by degraded soil and rocky habitats that will not allow the beech forest to settle in the whole potential habitat.

A large part of the subalpine region of Pelister mountain is covered by *Pinus peuce* forests. *Pinus peuce* forests are spreading even today to the montane and even the submontane vegetation belts on potential habitats of beech or beech–fir forests. This is a result of past land use, such as cutting and grazing, which degraded the sites and thus gave the less demanding species *Pinus peuce* a competitive advantage. The current process in the area of Pelister is also of course a result of good conservation practices in Pelister National Park and the abandonment of sheep breeding in

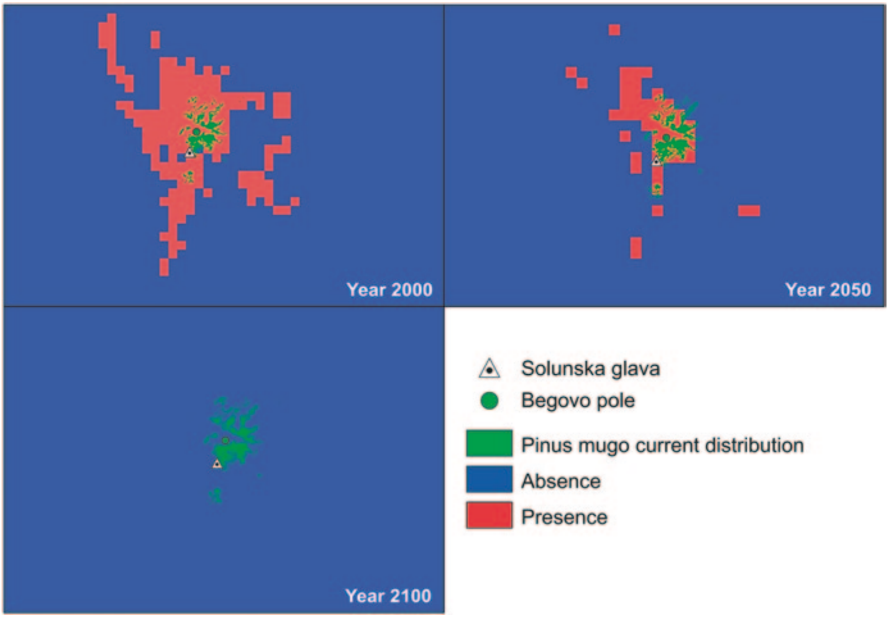

Fig. 7.7 Predicted distribution of *Pinus mugo* for the period to 2100. (After Melovski et al. 2013)

the region. Climate change will thus offer favorable conditions for *Pinus peuce*. *Pinus peuce* is an ecologically less demanding species than *Fagus sylvatica* and will therefore gain under further warming. A positive result can be expected, because the spread of *Pinus peuce* could also happen in a horizontal direction if biocorridors are safeguarded. *Pinus peuce* is known to have had a much larger distribution range in Macedonia historically (Meshinev et al. 2000).

Subalpine spruce forests in the area are at the southern limit of distribution. The timberline is built by spruce in the Alps, since spruce appears in areas with low temperature, low mineralization, and high snow cover. Warming will accelerate net mineralization, the snow will be converted to rain and spruce forests will therefore be endangered (Juvan et al. 2013). Fir forests and Scots pine communities will react in a similar way to beech forests.

Pinus mugo builds the timber line on Šar Planina and Jakupica. It builds large shrub communities only on Jakupica (Mt. Mokra) (Fig. 7.7). It covers habitats in the subalpine and alpine regions. The present distribution of *Pinus mugo* (indicated in green) is much smaller than the modeled one (red).The modeled distribution range is larger than the real distribution since the model predicts larger suitable habitat than those currently occupied. The problem is that the model does not take into account ecological factors (e.g., soil and bedrock types) and especially historic and anthropogenic factors. The model thus shows the potential distribution range. A considerable reduction of areas is expected in 2050 and the complete disappearance of *Pinus mugo* is expected by 2100.

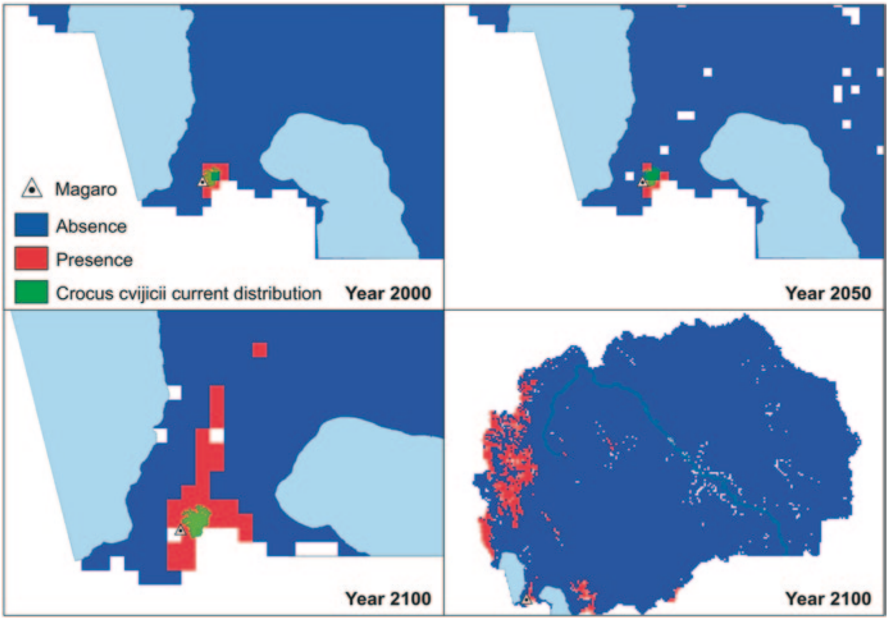

Fig. 7.8 Predicted distribution of *Crocus cvijici* for the period to 2100. (After Melovski et al. 2013)

Azonal communities, such as wetlands and riverine vegetation, can also be affected. The impact of climate change on wetlands and riverine vegetation is manifold. The water is warming, the ice-free period is longer and annual and seasonal water flow is changing. Wetlands can dry out and it is difficult for flora and vegetation to move to other places. The large floods induced by higher temperatures during snow melts in spring and the changed precipitation regime could also threaten the riverine flora and vegetation. An additional problem is the extraction of drinking water in the higher mountains, especially above the timberline.

7.11 Impact of Climate Changes on Alpine Flora and Vegetation

A rise in temperature will lead to shorter periods of snow packing on the mountains. Especially in mountains without a typical alpine belt, warming will affect species that grow around snow beds (e.g., *Crocus cvijicii* on Galičica). *Crocus cvijicii* is known to occur only on Galičica Mountain, in the subalpine region (1800–2150 m) on limestone. It flowers during late spring or early summer, mostly in humid sites near remaining snow patches (Ranđelović et al. 2007). The current distribution is presented in green polygons (Fig. 7.8). The modeled polygons are shown in red. The modeled area of distribution is larger, since the model shows all suitable sites

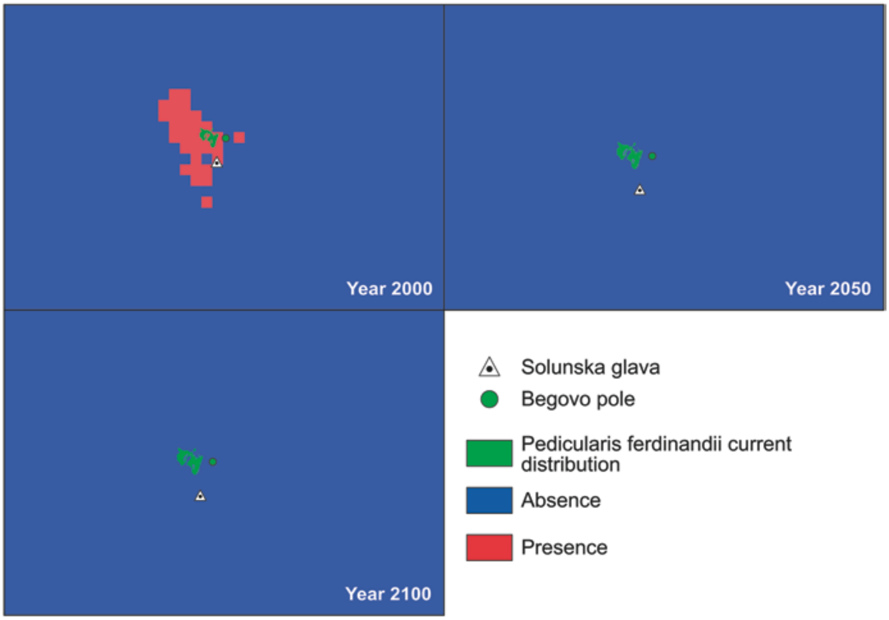

Fig. 7.9 Predicted distribution of *Pedicularis ferdinandi* for the period to 2100. (After Melovski et al. 2013)

for the species. However, it does not take into account ecological, historical, and anthropogenic influences. Climate change will shrink its potential distribution range. However, in 2100, the potential distribution range will expand and it will cover northern (lower) parts of Galičica. *Pedicularis ferdinandi* could serve as another example of alpine flora (Fig. 7.9). It is an endemic species of Jakupica and has several scattered localities at altitudes from 2100 to 2300 m, shown by green polygons. The modeled distribution is much larger, since it can be found in most of the areas in this region (red polygons). According to the model, this species will disappear by 2050.

Subalpine grasslands are of secondary origin (e.g., *Onobrychido-Festucion*), having been established in the subalpine belt on sites of subalpine forest ecosystems during past millennia and created through grazing practices. With global warming and in combination with the changing land use system (abandonment of grazing), these areas will be subject to afforestation.

Alpine grasslands, scree, and vegetation of cliffs are distributed only on the highest parts of the mountain summits that occupy a very small area (only 0.5 % of the country). The vertical movement of these communities will be hindered by relief obstacles, ecological conditions, and available space. The conical shape of mountains means a smaller area at higher elevations. The other possibility is that plants and communities will move to northern slopes, where ecological conditions are more propitious (cooler).

Well-developed alpine pastures can be found above 2100–2300 m, depending on the slope and aspect. Only the highest mountains in Macedonia have a real alpine region, since only Korab and Šar Planina have peaks above 2700 m. In these alpine areas, species are mostly arctic and glacial relicts, as well as endemics, the result of recent speciation. According to Beniston and Fox (1995), a rise of temperature of 3 °C corresponds to a change of altitude of 500 m. In that case, most of the present alpine vegetation would disappear. The only possibility for survival would be sheltered and north-facing slopes, which could provide conditions for the survival of alpine flora and communities.

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Chapter 8
Lupinus Species in Central Mexico in the Era of Climate Change: Adaptation, Migration, or Extinction?

Kalina Bermúdez-Torres, Maxime Ferval and Luc Legal

8.1 Introduction

The genus *Lupinus* L. (Fabaceae) gathers an uncertain number of annual and perennial plants as 200, 280, 300, and up to 500 species have been proposed without certainty by various authors (Dunn 1984; Eastwood et al. 2008; Kasprzak et al. 2006; Bermúdez-Torres et al. 2009). All these estimations demonstrate an important diversification of this genus. Lupines are mainly distributed in the New World (Fig. 8.1); in the Mediterranean basin, only a dozen of species (17–18 determined taxa at present) have been described (Alptekin et al. 1990).

The origin of this rather young genus goes back to the Oligocene (16 ± 5 Myrs BP) (Hughes and Eastwood 2006); however, its geographical origin has not been fully established, but is suspected to be European (Hughes and Eastwood 2006). As the species of this genus are distributed in America, Europe, and North Africa, the dispersion should be explained by the classical way of the Behring drift during the last glaciations. However, the total absence of species in Asia (Fig. 8.1) suggests an alternative route of colonization of America. The North Atlantic Land Bridge (NALB) has frequently been assumed for plant migration until the early Miocene (23–15 Myrs; Tiffney and Manchester 2001) and later plant migration between Old and New World is supposed to have occurred via dispersal mechanisms because of the closing of the NALB about 20–25 Myrs BP. However, Denk et al. (2010) have reconsidered this dating and claimed that migration along the NALB could occur much later until the late Miocene: Despite its discontinuity, the NALB could

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Fig. 8.1 Worldwide distribution of *Lupinu*s. (modified after Hughes and Eastwood 2006)

have represented a migration route for plants until 5–6 Myrs BP and also demonstrated for *Rhododendron* and *Quercus* (Milne 2004; Grímsson et al. 2007; Denk and Grimm 2010).

Three centers of diversification have been recognized in the New World: the Rocky Mountains, the Andes, and Mexico. In these regions, evolutionary radiations have been characterized and have led rapidly to a great variability of life-history traits (herbaceous, shrubby, and tree-like forms; annual and perennial life histories; allogamous and autogamous modes of fecundation; unifoliate and multifoliate plants), which are responsible for the complex taxonomic relationships among *Lupinus* species that constitute a tricky challenge to resolve (Drummond 2008; Hughes and Eastwood 2006). A question is remaining: Which are the traits or characters to be selected to classify *Lupinus* species? For example, some unifoliolated Brazilian species (such as *L. subsessilis*) are included in the same clade as East South American multifoliated species.

Based on sequences of the nonfunctional ribosomal region of Internal Transcribed Spacer (ITS) 1 and 2, it was possible to build a possible framework of phylogenetical relationships between *Lupinus* species all around the world. Sequences of 73 species covering the entire distribution area of *Lupinus* (Old and New World) were extracted from Käss and Wink (1997) and some original sequences of Mexican species were obtained by our group. Interestingly, species supposed to be more ancient (Europe/North Africa and East of America) produced well-defined groups and the topology of the tree was rather clear (Fig. 8.2). All these species grow at low or moderate elevation. Species assumed to be more recent (all the western part of America) show smaller distances and build a monophyletic group. The great majority of these species grow at high elevation with the notable exception of a group of species occurring at the sea level in dry and extreme temperature locations (Baja California, Mexico; California, Texas, Arizona, and Nevada, USA). Such distribution can be somehow analogous with Boreo-alpine species which occur at low elevation in the north of their distribution and at high elevation in the southern locations following a latitudinal gradient.

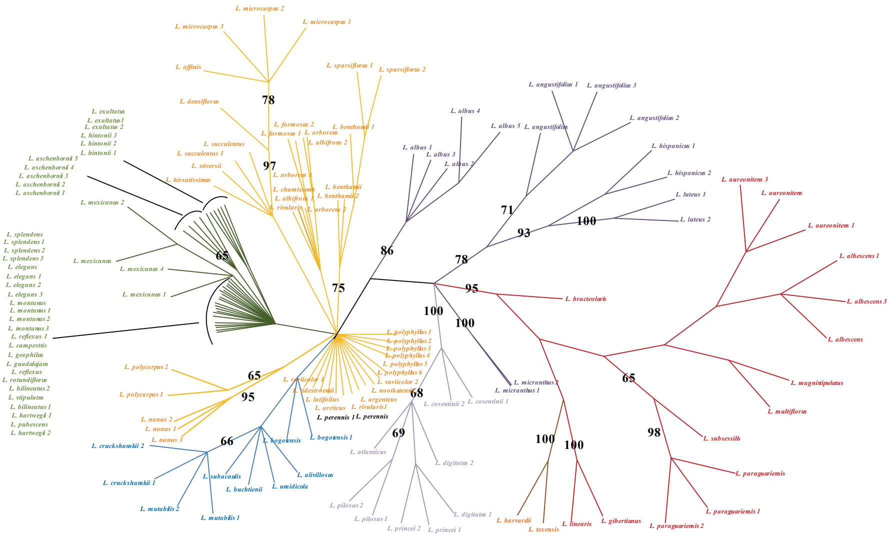

Fig. 8.2 World phylogeny of the genus *Lupinus* based on ITS' region. East of South America, west of South America (Andes), east of North America, west of North America (Rocky mountains), Mexico, Europe, and North Africa. Significant bootstrap values (>60 %) are indicated on branches

The genus is thought to have colonized North America >10 Myr BP. Drummond et al. (2012) showed that *Lupinus* diversified in western North America 5–13 Myr BP and in Mexico 1.2–3.5 Myr BP. South American species are not older than 2–3 Myr BP (Figs. 8.3, 8.4, 8.5, and 8.6).

8.2 Ecological and Physiological Traits of *Lupinus* Species

Physical barriers such as mountains, deserts, oceans, rivers, and also flooding, fires, volcanic eruptions, and human constructions (cities) determine geographical distribution of species. However, distribution of species is delimited not by physical barriers, but by climatic conditions; for example, temperature, soil and water chemistry gradients, and precipitation represent barriers to dispersal of species. Physiological traits determine the biogeographical distribution of species.

The genus *Lupinus* has a wide distribution, growing in a high variety of habitats, from desert valleys to tropical highlands, from high mountain regions to coastal plains, from acidic to calcareous soils, from alpine, temperate to subtropical (Wolko et al. 2011). While in Europe and North Africa, *Lupinus* is distributed in a small latitudinal interval (mostly around the Mediterranean Sea), in America, this genus shows a wide latitudinal distribution, going from Canada to Argentina, growing at a high variety of habitats. Are those the result of speciation that means genetic

Lupinus linearis (East Brazil). Low elevation. Photo: Eduardo LH Giehl 2010

Lupinus hispanicus (Europe). Low elevation. Photo: Javier Martin, 2009

Lupinus atlanticus (Morocco). Low elevation. Photo: Annie Garcin

Lupinus texensis (USA, Texas). Low elevation. Photo: sbs.utexas.edu

Lupinus polyphyllus (West USA) High elevation. Photo: Marilee Lovit

Lupinus mutabilis (Bolivia) High elevation. Photo: Emma Cooper, 2011.

Lupinus montanus (Central Mexico, Ajusco). High elevation. Photo: Luc Legal, 2011.

Lupinus concinnus (Baja California, Mexico) Low elevation. Photo: L. Kunte.

Fig. 8.3 Examples of various species of *Lupinus* in the world, each main clade is represented

divergence, or the result of phenological plasticity, which allows organisms to adapt to particular conditions?

The most primitive species are European taxa which grow all around the Mediterranean Sea, mainly on chalky dry hills. Growing in such ecosystem induces adaptation to soils with few nutriments, resistance to desiccation during long periods, and in most of species resistance to extremely high luminosity of open

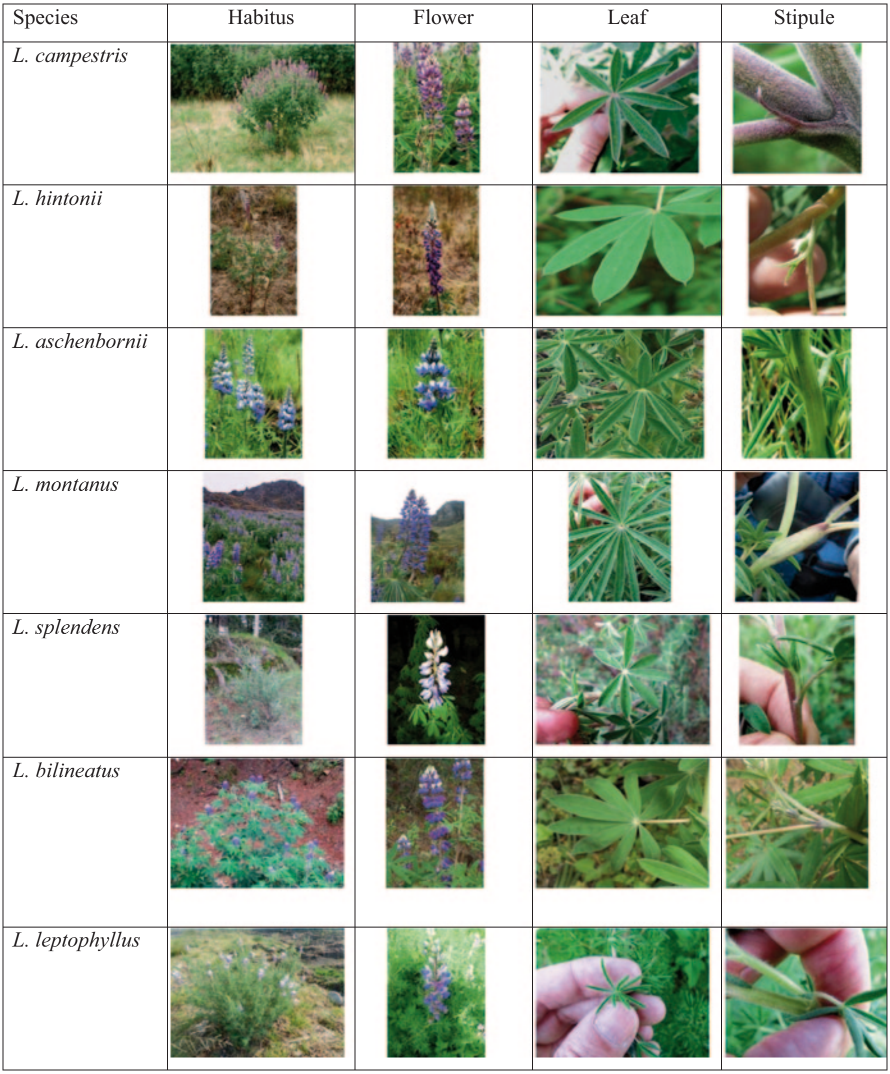

Fig. 8.4 Most representative Mexican *Lupinus* species in the main mountains of the Transvolcanic Axe. **a** *L. montanus,* Parque Nacional Izta Popo, **b** *L. aschenbornii,* Parque Nacional La Malinche, **c** *L. campestris,* Parque Nacional Pico de Orizaba, **d** *L. hintonii,* Parque Nacional Nevado de Toluca, **e** *L. splendens,* Parque Nacional El Ajusco, **f** *L. bilineatus,* Parque Nacional Nevado de Colima, and **g** *L. leptophyllus,* Parque Nacional La Malinche

fields of this region. These conditions are not fundamentally different from those of the dry locations where some species grow in Brazil and at a lower level all around the Gulf of Mexico (Texas to Florida). These conditions are also very similar for the species growing in the Mexican California, where most of species are found on dry chalky hills.

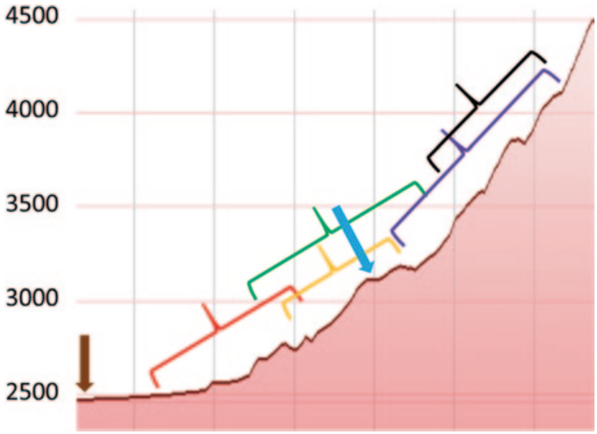

Fig. 8.5 Altitudinal (in meters) profile of distribution of Mexican Lupinus in the Parque Nacional Popocatepetl-Iztaccihuatl with the exception of L. leptophyllus on the way to Parque Nacional La Malinche. *L. campestris*, *L.bilineatus*, *L. hintonii*, *L. splendens*, *L. montanus* and *L. ashenbornii*.

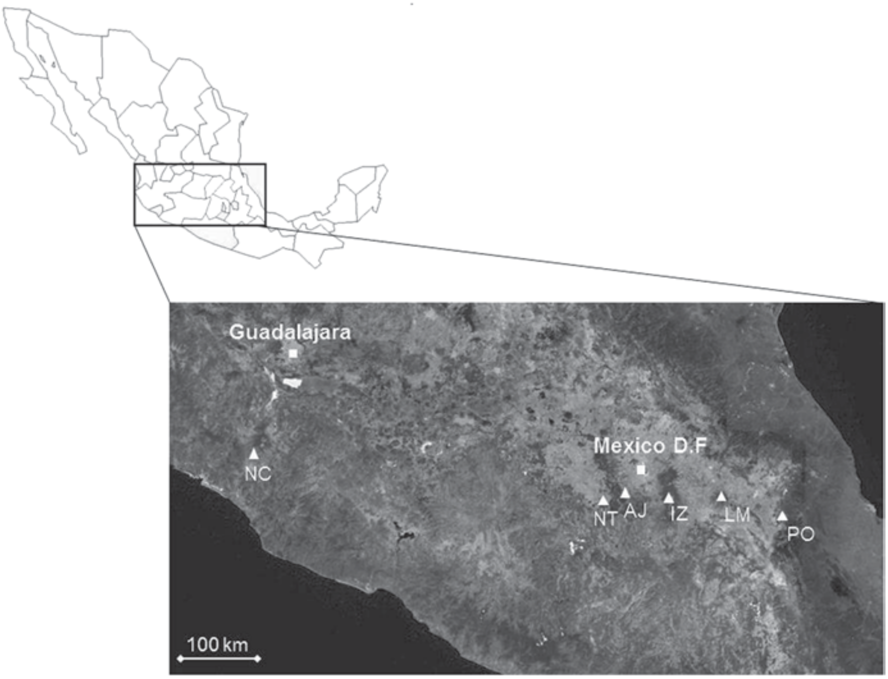

Fig. 8.6 Localities for *L. montanus* in the Trans-Mexican volcanic belt

More derived *Lupinus* species grow in some much cooler locations and most of species are found at high elevation or at least in zones where winter or night temperatures are regularly below 0 °C. In opposition with "primitive" lupins, most of these "younger" species grow on acidic soils, sometimes metamorphic but more often volcanic. Precipitations on these mountains can be high (especially in North America), but then *Lupinus* species grow only on very well drained soils. We may observe a tendency with more species growing below coniferous from Canada to Mexico, while a majority of species grows in open field in South America (Paramos: vegetation level above the forest).

In conclusion, this genus seems to be specialized in: (1) poor nutrient soils, (2) dry or well-drained soils, and (3) high amplitudes of temperature. Elevation, latitude, and longitude may separate some species groups but does not seem to be diagnostic and/or discriminant criteria at the scale of the genus, even if these criteria are most of time very discriminant when studying some of our model species, especially those growing on the highest locations.

To understand the global distribution and ecological constraints for the genus *Lupinus,* we have got to consider two important characteristics of this genus which determine the high plasticity and ability to conquer poor soils, and to be pioneers in succession processes. On the one side, plants of the genus *Lupinus* have the ability to associate with N_2 fixing bacteria of the genus *Bradyrhizobium* and, despite absence of mycorrhizal symbiosis, to mobilize phosphorous and other elements; and on the other side, the ability to synthesize quinolizidine alkaloids (QA), as a part of a strategy to inhibit growing of seedlings of other species (allelopathy) and as a defense against herbivores.

8.3 The Case of High-Elevation Mexican *Lupinus* Species

By integrating the characteristics of the sites where Mexican *Lupinus* species grow in central Mexico, we found some constrains with altitude, temperature, precipitations, soil type, soil pH, and vegetation, which allowed us to model the potential distribution of this genus.

The distribution of the Mexican *Lupinus* species follows the mountain chains, growing at a great interval of latitudes (from Chihuahua to Chiapas). In the northern latitudes, *Lupinus* grows at sea level (mainly species from Baja California). In Central Mexico, all the species grow above 1800 m asl, and up to 4500 m. The Transvolcanic Axe (TVA) shows the highest diversity of *Lupinus* species, distributed in such a characteristic altitudinal gradient, going from 1770 to 4387 m asl.

We can differentiate four altitudinal intervals, the first is very narrow and goes from 2400 to 2500 m asl; in this level, we found *L. leptophyllus* in the eastern elevations of La Malinche and Pico de Orizaba. In a second level, from 2600 to 3000 m asl, *L. campestris* grows alternatively with *L. bilineatus,* and is found in all high elevations of the TVA. The third level going from 3000 to 3500 m asl is characterized by the highest species diversity: *L. bilineatus, L. hintonii, L. splendens,* and

L. montanus; however, *L. hintonii* and *L. splendens* are distributed only in the western hills of the TVA. Finally, from 3600 to 4400 m asl, there are only two species: *L. montanus* and *L. aschenbornii,* which are distributed in all high elevations of the Trans-Mexican Volcanic Belt (TMVB).

Predominantly, soil type in the high mountains of the TMVB is loamy sand, the pH of eastern massifs (Pico de Orizaba and La Malinche) is comprised between 5.5 and 6.5, while western mountains have a more acidic soil (pH between 4.5 and 5.5). The predominant vegetation in all the distribution of *Lupinus* in the TMVB is pine oak and alpine meadow, temperatures are typically of the region, going from 0 °C in the cold season to around 25 °C in the warm season.

8.4 Genetic Polymorphism in an Altitudinal Gradient

As mentioned above, age of the colonization of *Lupinus* in Mexico can be dated from 1.2 to 3.45 Myr BP (Drummond et al. 2012; Ferval et al. 2013a). Most of bar-coding genes allowed us to have a resolution not better than 3–4 Myr, that is why we decided to use intersimple sequence repeat (ISSR) markers which possess a high rate of mutation even if the quality of phenotypic information is lower than allozymes. ISSR markers have been widely used to detect genetic diversity in plants (Ge et al. 2005a; Sica et al. 2005; Meloni et al. 2006; Alam et al. 2009; Escaravage et al. 2011; Gürkök et al. 2013). The ISSR technique presents several advantages: high reproducibility due to long primers that permit the use of stringent annealing temperatures (45–60 °C) and high polymorphism, including within a species (Pradeep Reddy et al. 2002). ISSR markers are dispersed and abundant throughout the genome, and no information about the sequences is necessary before amplification (Wink 2006). Finally, ISSR analysis only requires a small amount of plant material. Sequencing offers more absolute reliability but is based on very few variable characters, especially for recently radiated taxa, while ISSRs provide less confidence in the quality of the genetic information but this is positively balanced with a much greater quantity of information (Ferval et al. 2013b, 2014).

Lupinus montanus Kunth occurs from the North of Mexico to Guatemala following an island-like distribution and exhibiting substantial degrees of differentiation among populations despite the lack of morphological variation (Ferval et al. 2013a). Because of its wide distribution, this species represents a model for speciation and evolutive studies. Using ISSR, a total of 304 individuals of *L. montanus* were evaluated, representing 13 populations from 6 volcanoes of the TMVB: Nevado de Colima (NC: 2 populations), Nevado de Toluca (NT: 2 populations), Ajusco (AJ: 2 populations), Iztaccihuatl (IZ: 3 populations), La Malinche (LM: 2 populations), and Pico de Orizaba (PO: 2 populations).

As shown in Fig. 8.7, all the populations are clearly grouped and well separated from each other (Ferval et al. 2013a). Compared to results presented in this former work, we decided to present here a similar distance tree (mean distance, heuristic search) but without out-group and consequently unrooted (Fig. 8.7). We may note

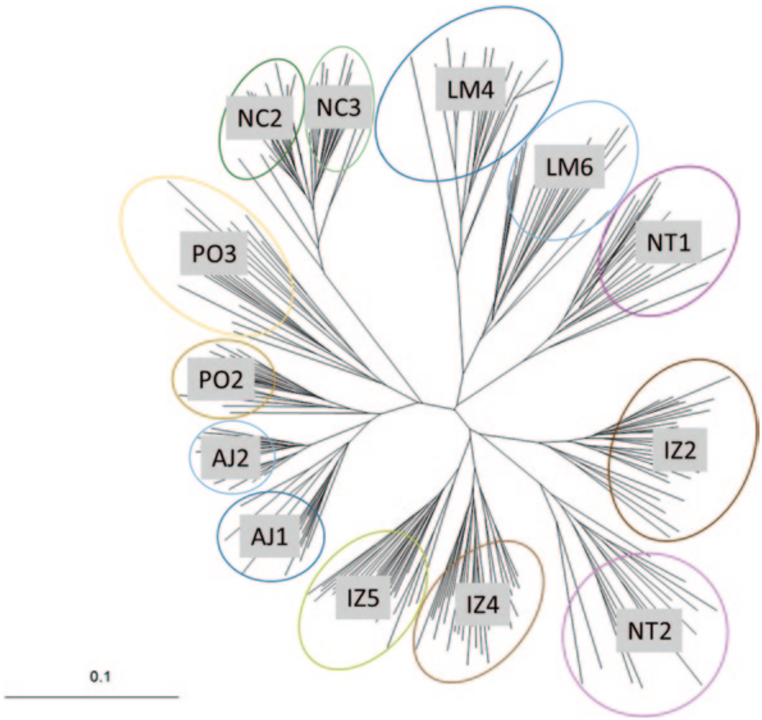

Fig. 8.7 Distance analysis of *L. montanus* populations. See codes in Table 8.1

Table 8.1 Evaluated *L. montanus* populations

Location code	Volcano	Population	Altitude (m)	Latitude (N)	Longitude (W)	Sample size
NC	Nevado de Colima (L. Pal.)	NC2	3787	19°35′3″	103°37′28″	27
		NC3	3624	19°33′6″	103°36′31″	25
NT	Nevado de Toluca (L. Pleisto.)	NT1	3940	19°7′28″	99°46′49″	24
		NT2	3727	19°8′1″	99°47′31″	17
AJ	Ajusco (01-P1)	AJ1	3551	19°11′60″	99°16′36″	23
		AJ2	3419	19°11′30″	99°19′58″	26
IZ	Iztaccihuatl (01-P1)	IZ2	3882	19°8′26″	98°38′54″	27
		IZ4	4174	19°8′29″	98°38′35″	26
		IZ5	3581	19°5′11″	98°39′42″	29
LM	La Malmche (01-P1)	LM4	3101	19°16′26″	98°2′32″	17
		LM6	3690	19°15′6″	98°1′44″	21
PO	Pico de Orizaba (L. Pleisto)	P02	3981	18°59′19″	97°17′56″	23
		P03	4387	19°0′28″	97°17′4″	19

L. Pal. Late Paleocene (65–50 Myr BP); *Ol–Pl* Oligocene–Pleistocene (30–1.7 Myr BP); *L. Pleisto.* Late Pleistocene (126,000–11,700 years BP)

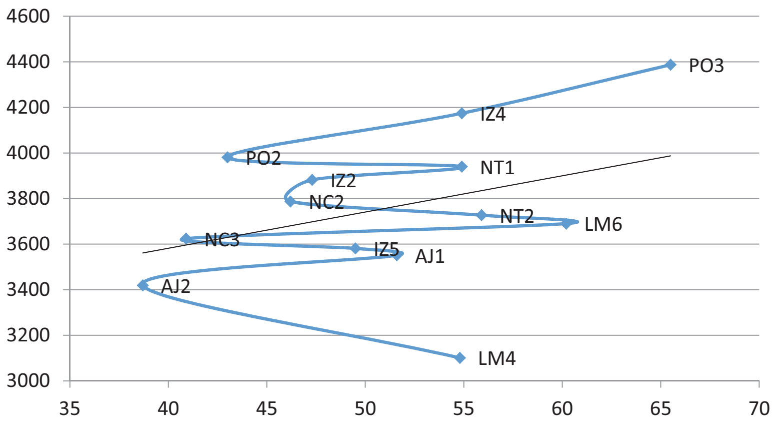

Fig. 8.8 Correlation between genetic polymorphism versus elevation of *L. montanus* populations. Codes in Table 8.1 (polymorphism values are given in Ferval et al. 2013a). *Black solid line* indicates tendency based on a deviance analysis under a Gaussian model

that all the populations belonging to a single volcano are grouped except the insertion of the NT2 population included in the IZ populations.

Populations and subpopulations were well separated on the basis of their genetic polymorphism (Ferval et al. 2013a). Using the same data, by plotting elevation versus polymorphism and performing an analysis of deviance following a Gaussian model, we obtain a Pr value of 0.1827 which is not significant, showing that, independently of the massif, there is no correlation between elevation and genetic polymorphism (Fig. 8.8), even if the solid black line (deviance analysis correlation line) seems to indicate a tendency of a greater polymorphism at higher elevations. This result was fully unexpected as most of reports show a negative correlation of genetic diversity and altitude (Cook 1985; Young et al. 2002). This phenomenon is mainly explained by a reduced number of pollinators which induce a greater clonality and self-reproduction (and so a lower polymorphism) for high-elevation plant populations (Cook 1985).

When taking into account the average of the differences (7 % on 1286 m) of Table 8.2, we have got an increase of 1 % of polymorphism every 183 m. This value is a bit greater when the base of calculation is done using the median value of these differences (median: 5.4 on 1286 m) with an increase of 1 % every 238 m.

Anyway, few examples are reported of an increase of genetic polymorphism with greater elevations such as those described for the Polygonaceae *Fagopyrum tataricum* in the Himalaya (Kishore et al. 2013). These authors explained this greater polymorphism at high elevation by the fact that lower temperature facilitates seed germination and by this way helps to increase the plant's genetic diversity. A balance seems to occur, at high elevation, between one side, the favored clonality + a decrease of potential pollinators, and on the other side, a greater germination + a lower competition which may favor greater populations and higher polymorphism.

Table 8.2 Differences of polymorphism between populations of *L. montanus*

	LM4	AJ2	IZ5	NC3	LM6	NT2	IZ2	NT1	PO2	% poly	Elevation (m)
LM4										54.8	3101
AJ2										38.7	3419
AJ1		12.9								51.6	3551
IZ5										49.5	3581
NC3										40.9	3624
LM6	5.4									60.2	3690
NT2										55.9	3727
NC2				5.3						46.2	3787
IZ2			-2.2							47.3	3882
NT1						-1.0				54.9	3940
PO2										43	3981
IZ4			5.4				7.6			54.9	4174
PO3									22.5	65.5	4387

Green positive differences; *Red* negative differences

In conclusion, *L. montanus* is a species which still has a potential to colonize higher elevations in a context of warming climate, and furthermore, this potential colonization will be favored by an increase of the polymorphism. Anyway, and following this same logic, polymorphism will be reduced for the lowest populations and the overall balance may be finally negative.

In order to understand not only the colonization events but also the restriction of the ecological niche depending on climate through time, a modeling procedure was performed (Fig. 8.9). We may notice that as expected for a high-elevation species, its distribution is much wider when overall temperature is low (last glaciation) but that distribution is almost the same actually than what is modeled during last interglacial period. During the Eemien period, the maximum of temperature was reaching +2 °C than actual mean temperature (15 °C vs. 13 °C actually; Cleveringa et al. 2000; Willerslev et al. 2007). It means that taking into account our model and for this species, an increase of 2 °C will not represent a cause of extinction. Anyway, most of recent predictions Intergovernmental Panel on Climate Change (IPCC) consider that temperature will increase from 1.8 to 3.4 °C until the end of this century. The problem is more of the speed of this increase rather than amplitude, even if some "fast" variations of temperature (10–15 °C on a 2000 years period in Greenland) were occurring during Eemian period (last interglacial), it seems that they were never overpassing 1 °C/century and more probably estimated to 0.5 °C maximum (Landais et al. 2003). Actual predictions are, therefore, three to six times faster increase which was never being registered; we have got, so far, no idea of how plant and animal species will adapt to such a fast change.

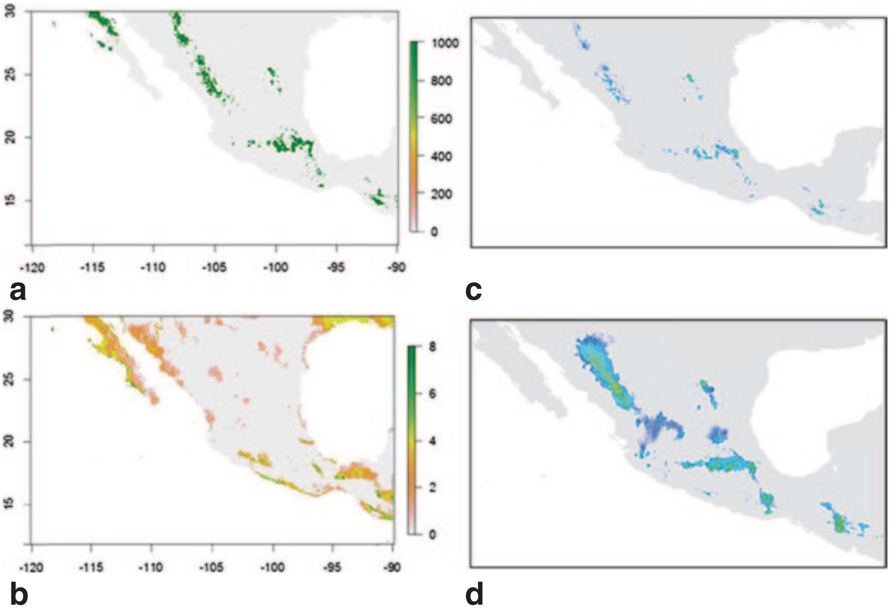

Fig. 8.9 Prediction of distribution of *L. montanus*. **a** current distribution; **b** error representation of our model based on receiver operating characteristic (ROC) and true skill statistic (TSS) threshold (*dark green*: 6–8 %; *light green*: 4–6 %; *light orange*: 2–4 % and *dark orange*: < 2 %); **c** last interglacial (LIG; ~ 120,000 to 140,000 years BP) distribution; **d** last glacial maximum (LGM; ~ 820121,000 years BP) distribution climate data were used to determine a model of the current, the last interglacial (LIG), and the last glacial maximum (LGM) range of *L .montanus* using the database from WorldClim (Hijmans et al. 2005). We considered the following set of variables: (1) annual mean temperature, (2) mean diurnal range (mean of monthly, maximum, and minimum temperature), (3) isothermality, (4) temperature seasonality, (5) maximum temperature of warmest month, (6) minimum temperature of coolest month, (7) annual temperature range, (8) mean temperature of wettest quarter, (9) mean temperature of driest quarter, (10) mean temperature of warmest quarter, (11) mean temperature of coldest quarter, (12) annual precipitation, (13) precipitation of wettest month, (14) precipitation of driest month, (15) precipitation seasonality, (16) precipitation of wettest quarter, (17) precipitation of driest quarter, (18) precipitation of warmest quarter, and (19) precipitation of coldest quarter. We used the best resolution available in the WorldClim database of 30 arc/s (926 m^2 at the equator) to model the ecological niche of *L. montanus*

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Chapter 9
Mountainous Vegetation of Central Black Sea Region

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9.1 Introduction

The vegetation of Central Black Sea Region belongs to Euxinian sector of Euro-Siberian phytogeographical region. In the east of Melet River, which flows through Ordu city, Colchic sector occurs. Mean annual precipitation in this region is higher than that in the western part of Melet River. The most diagnostic feature of the vegetation of Central Black Sea Region is the difficulty of the separation of different vegetation strata. It is too difficult to draw a demarcation line among communities

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Fig. 9.1 General aspect of the vegetation of Central Black Sea Region (Kutbay and Kılınç 1995)

in most vegetation types. The vegetation of Central Black Sea Region has been changed with elevation. The vegetation of Central Black Sea Region has been separated into three different groups, namely Mediterranean, prepontic, and Euxinian by Quezel et al. (1980). There are seven different vegetation strata, namely coastal Mediterranean strata, Mediterranean intrapontic strata, upper Mediterranean prepontic strata, mountainous prepontic strata, low mountain Euxine strata, high mountain Euxine strata, and subalpine Euxine strata in Central Black Sea Region from sea level to subalpine regions of mountains (Kutbay and Kılınc 1995; Özen and Kılınç 1995; Fig. 9.1).

9.2 Soil Traits

Brown and noncalcareous brown forest soils are widespread in higher parts of Central Black Sea Region. However, chestnut soils are also found especially in inner parts of the region. Clay loam and loamy textured soils are found in higher parts of Central Black Sea Region. Slightly and moderate alkaline soils are dominant, while *Fagus orientalis* associations occurred in moderate-to-extreme acidic soils. Organic matter content (%) of soils ranged from moderate to high. $CaCO_3$ (%) content of soils is low to moderate. However, soils under *Pinus* and steppe communities may be rich in $CaCO_3$ (Kutbay and Kılınc 1995; Cansaran and Aydogdu 2001; Cansaran et al. 2010; Korkmaz et al. 2011).

9.3 High Mountainous Vegetation of Central Black Sea Region

Mountainous prepontic strata is characterized by *Abies nordmanniana* (Stev.) Spach subsp. *bornmuelleriana* (Mattf.) Coode and Cullen and *F. orientalis* Lipsky mixed forests at 800–900 m. *Quercus pubescens* is also characteristic for this strata.

These forests are characterized by *Fago orientalis–Abietum nordmannianae* (Akman et al. 1983a). The diagnostic species of this association are *F. orientalis* and *A. nordmaniana* subsp. *bornmuelleriana*. *Rhododendro-Fagetalia orientalis* is characterized mainly by *Daphne pontica, Smilax excelsa, Hypericum androsaemum, Ilex colchica*, and *Rubus hirtus*. Querco-Carpinetalia orientalis is characterized by *Quercus petraea* subsp. *iberica, Carpinus betulus, Pyracantha coccinea, Cyclamen coum* var. *coum,* and *Asperula involucrata*. Carpino-Acerion alliance is represented by *Helleborus orientalis*. *Quercetea Pubescentis* class is represented by *Genista tinctoria, Hypericum perforatum, Campanula rapunculoides* subsp. *rapunculoides,* and *Cotinus coggyria*. *Fagetalia Sylvaticae* is represented by *Sanicula europaea* and *Cardamine bulbifera*. *Ulmus glabra, Hedera helix, Crataegus monogyna* subsp. *monogyna, Sambucus ebulus, Staphylea pinnata, Fragaria vesca, Euphorbia amygdaloides* var. *amygdaloides, Clinopodium vulgare* subsp. *arundanum, Geranium robertianum*, and *Campanula glomerata* are diagnostic species of Querco-Fagetea. These forests are widely destroyed mainly due to agricultural activities and only locally occurred. A.*nordmanniana* subsp. *bornmuelleriana* forests also penetrated in inner parts of Central Black Sea Region in Dutman Mountain around Alacam between 900-1400 m and represented by *Saniculo-Abietetum bornmuellerianae* on northern slopes. This association includes two subassociations namely *fagetosum orientalis* and *rhododendretosum lutei* (Ozen and Kılınc 1995). Prepontic strata is also characterised by *Carpino-Fagetum orientalis*. This association is found around Nebyan Mountain (Kutbay and Kılınc 1995) and southern parts of Alacam (Ozen and Kılınc 1995).

Q. pubescens forest is characteristic of mountainous prepontic strata and occurs in inner parts of Central Black Sea Region from 850 to 1200 m. However, they have not formed close canopies due to some disturbance factors (overgrazing, erosion, etc.) and canopy closure is rather low. These forests are represented by *Onobrychido tournefortii–Quercetum pubescentis* (Karaer et al. 1999) and *Leontodonto asperi–Quercetum pubescentis* (Cansaran and Aydogdu 2001). *Q. pubescens, Leontodon crispus* subsp. *asper* var. *asper, Myosotis arvensis* subsp. *arvensis,* and *Melampyrum arvense* var. *arvense* are diagnostic species of *Leontodonto asperi–Quercetum pubescentis* (Cansaran and Aydogdu 2001) association. *Lonicera caucasica* subsp. *orientalis, Laser trilobum,* and *Asyneuma rigidum* subsp. *rigidum* are some of the diagnostic species of *Carpino betuli–Acerion hyrcani* alliance. *Chamaecytisus pygmaeus, Astragalus glycyphyllos* subsp. *glycyphyllos, Colutea cilicica,* and *Polygala supina* are diagnostic species of *Querco cerridis–Carpinetalia orientalis* order. *Quercetea pubescentis* class is represented by *Cotoneaster nummularia, Dorycnium pentaphyllum* subsp. *herbaceum, Cotinus coggyria,* and *Lithospermum purpurocaeruleum*. Steppic species namely *Dactylis glomerata* subsp. *hispanica, Helianthemum nummularium* subsp. *nummularium, Polygala pruinosa* subsp. *pruinosa*, and *Festuca valesiaca* are diagnostic species of *Astragalo microcephali–Brometea tomentelli* class. *Q. pubescens, Onobrychis tournefortii,* and *Phlomis pungens* are diagnostic species of *Onobrychido tournefortii–Quercetum pubescentis* (Karaer et al. 1999). Steppic *Astragalo-Brometea* class is represented by *Astragalus microcephalus, Acantholimon acerosum, Iberis taurica, Helianthemum canum, Paronychia chionesa, Cruciata taurica*, and *Minuartia anatolica* var. *anatolica, Jurinea consanguinea, Allium flavum* subsp. *tauricum, Polygala pruinosa, Silene supina* subsp.

Fig. 9.2 *Fago orientalis–Abietum nordmannianae*. (Akman et al. 1983a)

pruinosa, Bungea trifida, Onobrychis armena, and *Helianthemum nummularium* are diagnostic species of steppic *Onobrychido–Thymetalia leucostomi* order. *Querco-Fagetea* class is represented by a few species namely *Lapsana communis, Geum urbanum, Epipactis helleborine, Campanula glomerata, Clinopodium vulgare,* and *Moehringia trinervia*. This strata is represented by *Corno mari-Quercetum cerridis* (Korkmaz et al. 2011) in inner parts around Vezirköprü and Osmancık (Çorum city) from 750 to 1250 m. *Quercus cerris* var. *cerris Carpinus orientalis* subsp. *orientalis Cornus mas* and *Scutellaria velenovsky* are diagnostic species of that association. This association is composed of two sub-associations, namely *loniceretosum etruscae* and *lathyretosum rosei*. *Lonicera etrusca* var. *etrusca Alliaria petiolata* and *Tanacetum parthenium* are differential taxa of *loniceretosum etruscae*, while *Lathyrus roseus, Nepeta nuda* subsp. *albiflora* and *Campanula rapunculoides* subsp. *rapunculoides* are differential taxa of *Lathyretosum rosei*. *Lathyrus laxiflorus* subsp. *laxiflorus, Asyneuma rigidum* subsp. *sibthorpianum, Vicia truncatula*, and *Viola sieheana* are some of the diagnostic species of *Carpino betuli–Acerion hyrcani* alliance. *Lathyrus tukhtensis, Colutea cilicica*, and *Trifolium medium* var. *medium* are some of the diagnostic species of *Querco cerridis–Carpinetalia orientalis* order. *Querco pseudocerridis–Cedretalia libani* order is represented by *Doronicum orientale* and *Vicia cracca* subsp. *stenophylla*. Some diagnostic species of *Quercetea pubescentis* class are *Silene italica, Geum urbanum, Epipactis condensata*, and *Crepis reuterana* subsp. *reuterana*. *Querco-Fagetea* class is represented by *Viola odorata, Athyrium filix-foemina,* and *Stellaria holostea*. *Juniperus oxycedrus* subsp. *oxycedrus, Ruscus aculeatus* var. *angustifolius, Geranium purpureum, Hedysarum varium,* and *Veronica orientalis* subsp. *orientalis* are some of the diagnostic species of *Quercetea ilicis* class (Korkmaz et al. 2011; Fig. 9.2).

In northern slopes at 900 m, low mountainous Euxine strata occurred and this strata is typically characterized by *F. orientalis–Castanetum sativae* (Akman et al. 1983b association, Fig. 9.3).

This association consists of tree, shrub, and herb layers. Characteristic species are *Castanea sativa, F. orientalis, Smilax excels,* and *Arum euxium*. *Rhododendro-Fagetalia orientalis* is characterized by *Rhododendron luteum, Vaccinium arctastaphyllos, Daphne pontica, Gentiana asclepiadea, Salvia forskahlei*, and *Trachystemon orientalis*. Querco-Carpinetalia orientalis is characterized by *Mespilus germanica,*

Fig. 9.3 *Fago orientalis–Castanetum sativae.* (Akman et al. 1983b)

Lathyrus laxiflorus subsp. *laxiflorus, Oenanthe pimpinelloides*, and *Dorynium pentaphllum* subsp. *anatolicum Hypericum perforatum, Coronilla varia*, and *Campanula rapunculoides* subsp. *rapunculoides* are the diagnostic species of Quercetea Pubescentis. Querco-Fagetea is represented by many species, namely *Populus tremula, Crataegus monogyna* subsp. *monogyna, Tamus communis* subsp. *communis, Veronica chamaedrys, Stachys sylvatica*, and *Poa nemoralis*.

Above 800 m, mountainous Euxine strata occurs. This strata is characterized by pure *F. orientalis* forests and *Pinus sylvestris* L. forests in northern slopes, while in southern slopes *Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe forests are replaced. Pure *F. orientalis* are widespread in Central Black Sea Region. In Eastern Black Sea Region, pure *F. orientalis* forests are not found and these forests are usually replaced by *Picea orientalis* forests. *F. orientalis* forests usually form mixed forests with the other deciduous species in Eastern Black Sea Region.

Rhododendron luteum, Veronica magna, and *Prenanthes cacaliifola* are the diagnostic species of *Rhododendro-Fagetum orientalis* (Kutbay and Kılınc 1995) association. Diagnostic species of Rhododendro-Fagetalia orientalis are *Hypericum androsaemum, Daphne pontica, Rubus hirtus, Salvia forskahlei*, and *Gentiana asclepiadea*. Querco-Carpinetalia orientalis is represented by a few species, namely *H. orientalis, Cyclamen coum* var. *coum*, and *Lathyrus laxiflorus* subsp. *laxiflorus*. However, Querco-Fagetea is represented by many species, namely *Populus tremula, Ulmus glabra, Stachys sylvatica, Cardamine impatiens* var. *pectinata, C. bulbifera*, *Salvia forskahlei, S. glutinosa*, and *Geranium robertianum* (Kutbay and Kılınc 1995). Pure *F. orientalis* forests are also widespread in inner parts of Black Sea Region in northern slopes. For example, *Veronico melissaefoliace–Fagetum orientalis* (Quezel et al. 1980) association is occurrs around Erbaa in Kelkit valley (Karaer et al. 1999). *F. orientalis, Veronica magna, Arum euxinum,* and *Salvia glutinosa* are the diagnostic species of this association. *Veronico-Fagion* alliance is represented by *Veronica peduncularis* and *Arum orientale*. *Cardamine bulbifera* and *Neottia nidus-avis* are the diagnostic species of *Fagetalia sylvatica*. Two prominent species of this association are *Cyclamen coum* var. *caucasica* and *Paris incompleta* which are the diagnostic species of *Pino-Piceetalia orientalis*. *Quercetea Pubescentis* are represented by *Doronicum orientale, Tanacetum parthenium*, and

Cephalanthera rubra. *Rhododendro-Fagetum orientalis* and *Querco-Fagetea* are also represented in this association. *Myosotis alpestris, Luzula forsteri*, and *Brachypodim sylvaticum* are most prominent species in herb layer of *Querco-Fagetea*. *F. orientalis* forests are also found in inner parts of river valleys. In Kızılırmak valley, *Galio odorati-Fagetum orientalis* (Özen and Kılınç 2002) is found from 1250 to 1500 m. *F. orientalis, Lathyrus aureus, Galium odoratum*, and *Melica uniflora* are diagnostic species of that association. This association comprises two subassociations. *A. nordmanniana* subsp. *bornmuelleriana, Pyrola media, Moneses uniflora, and Orthilia secunda* are differential species of *Abietetosum bornmuellerianae*, while *Vicia crocea, Poa pratensis*, and *Astragalus glycyphyllos* subsp. *glycyphylloides* are differential species of *Vicietosum* croceae. *Carpinus betulus, Lonicera caucasica* subsp. *orientalis, Crataegus tanacetifolia, Cyclamen coum* var. *coum*, and *Lathyrus laxiflorus* subsp. *laxiflorus* are diagnostic species of *Carpino betuli–Acerion hyrcani* alliance. *Querco cerridis–Carpinetalia orientalis* is represented by *Euonymus latifolius* subsp. *latifolius, Sorbus torminalis* var. *torminalis, Knautia involucrata, Dorycnium pentaphyllum* subsp. *herbaceum*, and *Primula vulgaris* subsp. *vulgaris*. *Vicia cracca* subsp. *gerardi, Sorbus umbellata* var. *umbellata*, and *Doronicum orientale* are diagnostic species of *Querco pseudocerridis–Cedretalia libani* order. *Quercetea pubescentis* class, *Fagetalia sylvaticae*, and *Rhododendro pontici–Fagetalia orientalis* order are also represented and their floristic composition is similar to the other *F. orientalis* associations. This strata also penetrated the inner parts. For example, *Crataego microphyllae–Carpinetum betuli* (Cansaran and Aydogdu 2001) is found around Egerli Mountain (Amasya city) from 1000 to 1230 m. Diagnostic species of this association is *Carpinus betulus, Crataegus microphylla, Prunus spinosa* subsp. *dasyphylla, Echinops galaticus,* and *Achillea millefolium* subsp. *pannonica*. The floristic composition is similar to *Populo tremulae–Quercetum syspirensis* (Cansaran and Aydogdu 2001; Fig. 9.4).

F. orientalis forests are also found in inner parts of Central Black Sea Region where oceanic climate is seen. *Euonymo verrucosi–Fagetum orientalis* (Cansaran et al. 2010) is found around Borabay Lake (Amasya city) and diagnostic species

Fig. 9.4 *Rhododendro-Fagetum orientalis*. (Kutbay and Kılınc 1995)

Fig. 9.5 *Daphno pontica–Pinetum sylvestris*. (Ekim and Akman 1991)

are *Euonymus verrucosus* Scop. *Draba rigida* Willd. var. *rigida, Symphytum bornmuelleri* Bucknall, *Melampyrum arvense* L. var. *arvense, Epimedium pubigerum* (DC.) Morr. & Decne, and *Heracleum platytaenium* Boiss. *Carpino betuli–Acerion hyrcani* alliance is represented by *Carpino betuli–Acerion hyrcani, Cyclamen coum* Miller var. *coum, Asperula involucrata* Wahlenb. *Querco cerridis–Carpinetalia orientalis* order is represented by *Trifolium pannonicum* Jacq. subsp. *elongatum* (Willd.) Zoh., *Coronilla varia* L. subsp. *varia, Lathyrus aureus* (Stev.) Brandza, *Vicia cracca* L. subsp. *stenophylla* Vel., *Viburnum lantana* L., and *Cephalanthera rubra* (L.) L.M.C. Richard are the diagnostic species of *Quercetea pubescentis* class. The most diagnostic species of *Querco-Fagetea* class are *Rubus hirtus* Waldst. & Kit., *Lapsana communis* L. subsp. *intermedia* (Bieb.) Hayek, and *Geum urbanum* L.

P. sylvestris forests also belong to Euxine strata. These forests are characterized by *Daphno pontica–Pinetum sylvestris* (Ekim and Akman 1991) association which includes tree, shrub, and herb layers (Fig. 9.5).

Carpinus orientalis subsp. *orientalis, Geranium asphodeloides* subsp. *asphodeloides,* and *Polygala supina* are diagnostic species of *Querco-Carpinetalia orientalis*. *H. orientalis, Lathyrus laxiflorus* subsp. *laxiflorus,* and *Cyclamen coum* var. *coum* are diagnostic species for *Carpino-Acerion*. *Pino-Piceetalia orientalis* and *Rhododendro-Fagetalia orientalis* are represented by a single species, namely *A. nordmanniana* subsp. *bornmuelleriana* and *Rubus hirtus*, respectively. *Pinus. nigra* subsp. *pallasiana, Pyracantha coccinea, Ligustrum vulgare,* and *Trifolium pannonicum* subsp. *elongatum* are diagnostic species of *Quercetea Pubescentis*. *Querco-Fagetea* are represented by *Primula vulgaris* subsp. *sibthorpii, Salvia forskahlei, Fragaria vesca, Brachypodium sylvaticum*, and *Teucrium chamaedrys* subsp. *chamaedrys*. *P. sylvestris* forests are also distributed in inner parts of Central Black Sea Region like *F. orientalis* forests. These forests is also found in Dutman Mountain around Alacam between 1000-1400 m in iner parts of Central Black Sea Region and represented by Abieti-Pinetum sylvestris association (Özen and Kılınç 1995). *P. sylvestris, Ranunculus buhsei* Boiss, *Juniperus communis* subsp. *alpina, Daphne pontica* L., *Crepis macropus* Boiss & Heldr., and *Pyrola media* Swartz are diagnostic species of *Ranunculo buhsei–Pinetum sylvestris* (Karaer et al. 1999) association.

This association occurred between 1350 and 1480 m. *Carpino-Acerion* alliance is represented by *Asperula involucrata, Lathyrus laxiflorus, L. aureus, Tanacetum poteriifolium,* and *H. orientalis*. Floristic composition of *Quercetea Pubescentis* is similar to *Daphno pontica–Pinetum sylvestris* association except for *Euonymus verrucosus* and *Sorbus torminalis*. Floristic composition of *Rhododendro-Fagetalia orientalis* and *Querco-Fagetae* is very similar to *Daphno pontica–Pinetum sylvestris* association. *P. sylvestris* forests also formed closed canopies around Kızılırmak valley at 1600 m. The diagnostic species of *Rumi scutati–Pinetum hamatae* (Korkmaz et al. 2011) association are *P. sylvestris* var. *hamata, Juniperus communis* var. *saxatilis, Myosotis lithospermifolia, Rumex scutatus*, and *Potentilla speciosa* subsp. *speciosa*. *Chamaecytisus pygmaeus* and *Ranunculus illyricus* subsp. *illyricus* are diagnostic species of *Carpino betuli–Acerion hyrcani* alliance. *Bunium microcarpum* subsp. *bourgaei, Geranium macrostylum*, and *Genista lydia* var. *lydia* are some of the diagnostic species of *Querco pseudocerridis–Cedretalia libani* order. *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis* class, and *Rhododendro pontici-Fagetalia orientalis* order and *Fagetalia sylvaticae* order are also represented by several species and their floristic compositions are very similar to the other associations. *Astragalus squalidus, Thymus praecox* subsp. *jankae* var. *jankae, Poa bulbosa, Stachys iberica* subsp. *iberica* var. *iberica, Cynoglossum montanum*, and *Melica ciliata* subsp. *ciliata* are some of the diagnostic species of *Astragalo microcephali–Brometea tomentelli* class. The representation of Astragalo microcephali–Brometea tomentelli indicates the effects of continental climate in *P. sylvestris* forests along stream valleys. *P. sylvestris* also penetrates the inner parts of Central Black Sea Region between 1200 and 1700 m in subalpine region. *Petrorhagio olympicae–Pinetum sylvestris* (Cansaran and Aydogdu 2001) is found between 1400 and 1500 m. *P. sylvestris, Juniperus communis* subsp. *alpina, Petrorhagia alpina* subsp. *olympica*, and *Lathyrus tukhtensis* are diagnostic species of that association. The floristic composition of *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, and *Quercetea pubescentis* and steppic *Astragalo microcephali–Brometea tomentelli* are very similar to that of the other *P. sylvestris* associations. The other subalpine *P. sylvestris* association is *Lathyro tukthensis–Pinetum sylvestris* (Cansaran et al. 2010) association. *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis* class, and *Querco-Fagetea* class are represented by several species.

In southern slopes, Euxine strata is characterized by *P. nigra* subsp. *pallasiana* forests and different associations are formed. *Genisto tinctorae–Pinetum nigrae* (Kutbay and Kılınc 1995) is widespread at high altitudes around Samsun city from 850 to 1150 m (Fig. 9.6).

Carpino-Acerion is represented by *H. orientalis, Viola siehana,* and *Lathyrus laxiflorus* subsp. *laxiflorus*. *Carpinus orietalis* subsp. *orientalis, Argyrolobium biebersteinii, Polygala supina,* and *Dorycnium pentaphyllum* subsp. *anatolicum* are the diagnostic species of *Querco-Carpinetalia orientalis*. *Quercetea Pubescentis* is represented by *Juniperus oxycedrus* subsp. *oxycedrus, Acer campestre* subsp. *campestre, Ligustrum vulgare, Sorbus torminalis* var. *pinnatifida, Hypericum perforatum, Cornus mas,* and *Cotinus coggyria*. *Cisto-Micromerietea* class belong-

Fig. 9.6 *Genisto tinctorae–Pinetum nigrae*. (Kutbay and Kılınc 1995)

ing to Mediterranean region is also represented by *Origanum vulgare* subsp. *vulgare, Salvia tomentosa*, and *Teucrium polium*. This shows that Mediterranean climate can be penetrated to high altitudes in Black Sea Region and it is impossible to separate different vegetation layers in some cases (Kutbay and Kılınc 1995). *Rhododendro-Fagetalia orientalis* is represented by *Ilex colchica, Rhododendron luteum, Daphne pontica,* and *Salvia forskahlei*. *F. orientalis, A. nordmanniana* subsp. *bornmuelleriana, Crataegus monogyna* subsp. *monogyna, P. sylvestris, Hedera helix, Cardamine bulbifera, Primula vulgaris* subsp. *sibthorpii, Clinopodium vulgare* subsp. *arundanum, Salvia glutinosa, Geranium robertianum, Lapsana communis* subsp. *intermedia, Fragaria vesca, Neottia nidus-avis,* and *Sanicula europaea* are diagnostic species of *Querco-Fagetea*. In inner parts of Central Black Sea Region, *P. nigra* subsp. *pallasiana* forest is represented by *Astragalo aucheri–Pinetum pallasianae* (Karaer et al. 1999) around Erbaa from 1000 to 1100 m and *Junipero-Pinetum nigrae* association in Kunduz Forests, Vezirköprü (Özen and Kılınç 2002).

Characteristic and differential species of the association are *Pinus nigra* subsp. *pallasiana*, *Juniperus oxycedrus* subsp. *oxycedrus* and *Dorycnium pentaphyllum* subsp. *anatolicum*. Characteristic species of different syntaxonomic units are found in that association. *Rhododendro-Fagetalia orientalis, Quercetea ilicis, Quercetea pubescentis* and *Querco-Carpinetalia orientalis* are represented in *Junipero-Pinetum nigrae*. The representation of *Cisto-Micromerietea* indicates antropogenic impact (Özen and Kılınç 2002).

The floristic composition of *Astragalo aucheri -Pinetum pallasianae* is different from *Genisto tinctorae–Pinetum nigrae* and it has a steppic character. Steppic *Astragalo-Brometea* class is represented by *Hypericum lydium, Linaria coriifolia, Fibigia eriocalycina, Polygala pruinosa, Minuartia anatolica* var. *anatolica,* and *Pilosella hoppeana*. *Jurinea consanguinea, Silene supina* subsp. *pruinosa,* and *Salvia cryptantha* are diagnostic species of steppic *Onobrychido-Thymetalia leucostomi* order. *Querco–Carpinetalia orientalis* order and *Carpino-Acerion* alliance are also represented and their floristic compositions are similar to *Genisto tinctorae–Pinetum nigrae*. In Kızılırmak valley, *Trifolio canescentis–Pinetum caramanicae*

(Korkmaz et al. 2011) is found between 1100 and 1250 m. *Pinus nigra* subsp. *pallasiana* var. *caramanica, Q. pubescens, Trifolium canescens, Rubus canescens* var. *canescens, Cistus laurifolius,* and *Polygala anatolica* are diagnostic species. *Carpinus betulus, Tanacetum poteriifolium, Lathyrus tukhtensis,* and *Cirsium hypoleucum* are diagnostic species of *Carpino betuli–Acerion hyrcani* alliance. *Vicia cracca* subsp. *stenophylla, Doronicum orientale, Sorbus umbellata* var. *umbellata,* and *Genista lydia* var. *lydia* are diagnostic species of *Querco pseudocerridis–Cedretalia libani* order. *Epipactis condensata,* and *Limodorum abortivum* are some of the diagnostic species of Qu*ercetea pubescentis* class. *Polygonatum multiflorum* and *Neottia nidus-avis* are character species of *Fagetalia sylvaticae* order. *Querco cerridis–Carpinetalia orientalis* order and *Querco-Fagetea* class are also represented by several species which are very similar to the other *P. nigra* associations. *Astragalo microcephali–Brometea tomentelli* class is represented by several species, namely *Anthemis tinctoria* var. *pallida, Galium verum* subsp. *glabrescens Koeleria cristata,* and *Alyssum murale* var. *murale*. The floristic composition of *Trifolio canescentis–Pinetum caramanicae* (Korkmaz et al. 2011) includes Euxinian, Mediterranean, and steppe species because stream valleys have been influenced by oceanic, continental, and Mediterranean climates. *Pinus nigra* J.F. Arnold subsp. var. *caramanica* (Loudon) Rehder has also formed associations in inner parts of Central Black Sea Region above 1000 m. For example, *Chamaecytiso pygmaei–Pinetum pallasianae* (Cansaran and Aydogdu 2001) is found between 1230 and 1280 m. *Pinus nigra* subsp. *pallasiana, Chamaecytisus pygmaeus,* and *Juniperus oxycedrus* subsp. *oxycedrus* are the diagnostic species of that association. *Carpino betuli–Acerion hyrcani* alliance is represented by *Carpinus betulus, Lathyrus tukhtensis, Tanacetum poteriifolium, Cyclamen coum* var. *coum,* and *Lonicera caucasica* subsp. *orientalis*. Diagnostic species of *Querco cerridis–Carpinetalia orientalis* order and *Quercetea pubescentis* class are similar to that of the other *P. nigra* subsp. *pallasiana* associations. Steppic *Astragalo microcephali–Brometea tomentelli* class is represented by *Festuca jeanpertii* subsp. *jeanpertii, Anthemis tinctoria* var. *tinctoria Helianthemum nummularium* subsp. *nummularium, Teucrium chamaedrys* subsp. *chamaedrys*. *Galium verum* subsp. *verum* and *Alyssum murale* var. *murale*. One of the most diagnostic *P. nigra* subsp. *pallasiana* association is *Digitalido lamarckii–Pinetum caramanicae* (Cansaran et al. 2010). *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia* orientalis order, and *Quercetea pubescentis* class are represented by several species like *Lathyro tukthensis–Pinetum sylvestris* (Cansaran et al. 2010) association. *Querco-Fagetea* class is also represented.

Oceanic climate can be penetrated in inner parts of Central Black Sea Region. *Crataego microphyllae–Carpinetum betuli* (Cansaran and Aydogdu 2001) is found between 1000 and 1230 m. *Carpinus betulus, Crataegus microphylla, Prunus spinosa* subsp. *dasyphylla, Echinops galaticus,* and *Achillea millefolium* subsp. *pannonica* are diagnostic species of this association. Floristic composition composed of the diagnostic species of *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis,* and *Astragalo microcephali–Brometea tomentelli* classes and diagnostic species of those syntaxonomic units are similar to those of the other associations. In more moist parts of inner parts of Central Black Sea Region, *Populo tremulae–Quercetum syspirensis* (Cansaran and Aydogdu 2001) association is also found from 1275 to 1350 m. *Quercus macranthera* subsp. *syspirensis* and *Populus tremula* are diagnostic species of that association. Diagnostic species of *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis* and *Astragalo microcephali–Brometea tomentelli* classes are represented.

A peculiar characteristic of Central Black Sea Region is the penetrance of Mediterranean climate to the inner parts. Mediterranean maquis and phrygana vegetation occur from sea level to 500 m. However, Mediterranean-type vegetation is also found above 1000 m in inner parts, especially along stream valleys (Kutbay and Kılınc 1995; Cansaran and Aydogdu, 2001; Karaer et al. 2010). For example, *Trifolio hirti-Cistetum laurifolii* (Cansaran and Aydogdu 2001) is found around Amasya city from 1000 to 1050 m. *Cistus laurifolius, Trifolium hirtum, Medicago coronata, Genista tinctoria, Lathyrus sphaericus, Psoralea bituminosa,* and *Scutellaria salviifolia* are diagnostic species. Diagnostic species of *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis, Astragalo microcephali–Brometea tomentelli,* and *Querco–Fagetea* class are represented in that association (Cansaran and Aydogdu 2001). In inner parts of Central Black Sea Region, it is also possible to see the effects of Mediterranean climate even in high altitudes and Mediterranean-type vegetation occurred above 1000 m. *Trifolio hirti–Cistetum laurifolii* (Cansaran and Aydogdu 2001) is found between 1000 and 1050 m. Diagnostic species are *Cistus laurifolius, Trifolium hirtum, Medicago coronata, Genista tinctoria, Lathyrus sphaericus, Psoralea bituminosa,* and *Scutellaria salviifolia*. Diagnostic species of *Carpino betuli–Acerion hyrcani* alliance, *Querco cerridis–Carpinetalia orientalis* order, *Quercetea pubescentis,* and *Astragalo microcephali–Brometea tomentelli* classes are represented. This also shows the difficulty of drawing a border between different vegetation types in Central Black Sea Region because different climate types are mixed (Kutbay and Kılınc 1995).

In inner parts of Central Black Sea Region, continental climate is seen. Steppe vegetation is found above 1000 m.

Steppe vegetation is seen especially along stream valleys. For example, *Daphno oleoidis–Astragaletum angustifolii* (Korkmaz et al. 2011) belongs to Mountainous Prepontic Belt and found in Kargı (Çorum city) between 1600 and 1700 m. *Astragalus angustifolius* subsp. *angustifolius* var. *angustifolius, Daphne oleoides* subsp. *oleoides, Marrubium cephalanthum, Euphorbia erythrodon, Euphorbia anacampseros* var. *anacampseros*, and *Polygala alpestris* are diagnostic species of that association. *Helianthemum nummularium* subsp. *tomentosum, Thymus spyleus* subsp. *rosulans, Teucrium chamaedrys* subsp. *chamaedrys, Myosotis alpestris* subsp. *alpestris, and Poa alpina* subsp. *fallax* are diagnostic species of *Onobrychido armenae–Thymetalia leucostomi* order. *Astragalo microcephali–Brometea tomentelli* class is represented by *Asperula nitida* subsp. *subcapitellata, Plantago holosteum, Hypericum orientale, Veronica orientalis* subsp. *orientalis, Hypericum linarioides, Erysimum smyrnaeum, Iberis taurica, Ajuga chamaepitys* subsp. *chia* var. chia, and *Helianthemum canum*. *Quercetea pubescentis* class is represented by only a few species (*Bunium microcarpum* subsp. *bourgaei, Carex halleriana,* and *Rubus canescens* var. *glabratus*). *Linario corifoliae–Astragaletum microcephali* (Korkmaz et al. 2011) is found around Kargı and Osmancık (Çorum city) between 550 and 1300 m. *Astragalus microcephalus Callipeltis cucullaria* and *Linaria corifolia* are diagnostic species of that association. This association is composed of two subassociations, namely *stipetosum arabico* and *alyssetosum desertorum*. *Stipa arabica, Onosma isauricum, Erysimum crassipes,* and *Silene subconica* and *Alyssum desertorum* var. *desertorum, Morina persica* var. *persica, Bromus benekenii,* and *Cruciata pedemontana* are diagnostic species of *stipetosum arabico* and *alyssetosum desertorum*, respectively. *Lappula barbata, Ziziphora tenuior, Taeniatherum caput-medusae* subsp. *crinitum,* and *Ziziphora taurica* subsp. *taurica* are diagnostic species of *Astragalo karamasici-Gypsophilion eriocalycis* alliance. *Onobrychido armenae-Thymetalia leucostomi order* is represented by several species, namely *Astragalus leucothrix, Acantholimon acerosum* var. *acerosum,* and *Nepeta nuda* subsp. *albiflora. Logfia arvensis, Alkanna orientalis* var. *orientalis, Apera intermedia, Centaurea urvillei* subsp. *urvillei,* and *Hypericum origanifolium are* some of the diagnostic species of *Astragalo microcephali–Brometea tomentelli* class. Steppe vegetation is also widespread in inner parts of Central Black Sea Region where continental climate is dominant. For example, *Stachyi byzantinae–Astragaletum microcephali* (Cansaran and Aydogdu 2001) is found between 1050 and 1150 m in Eregli Mountain, Amasya city. *Astragalus microcephalus, Stachys byzantina, Carduus acanthodies* subsp. *acanthoides, Elymus repens* subsp. *elongatiformis, Peucedanum palimbioides, Alkanna orientalis* var. *orientalis, Astrodaucus orientalis, Verbascum caudatum, Paracaryum ancyritanum,* and *Astragalus albifolius* are diagnostic species of that association. *Teucrium chamaedrys* subsp. *chamaedrys, Marrubium parviflorum* subsp. *parviflorum,* and *Phlomis armeniaca* are diagnostic species of *Phlomido armeniacae–Astragalion microcephali* alliance. *Scabiosa argentea, Silene supina* subsp. *pruinosa,* and *Alyssum pateri* subsp. pateri are diagnostic species of *Onobrychido armenae–Thymetalia leucostomi* order. *Scutellaria orientalis* subsp. *pinnatifida, Acantholimon acerosum* (Willd.) Boiss. var. *acerosum,* and *Thymus sipyleus* subsp. *rosulans* are some of the diagnostic species of *Astragalo microcephali–Brometea tomentelli* class. In subalpine region of Amasya city, steppic *Saponario prostratae–Astragaletum microcephali* (Cansaran et al. 2010) association is found. Diagnostic species of this association are *Astragalus microcephalus* Willd., *Saponaria prostrata* Willd. var. *prostrata, Paracaryum ancyritanum* Boiss., *Cruciata laevipes* Opiz, *Paracaryum paphlagonicum* (Bornm.) R. Mill, and *Astragalus acmophyllus* Bunge. *Phlomido armeniacae–Astragalion microcephalit alliance* is characterized by *Teucrium chamaedrys* L. var. *chamaedrys*. *Linaria corifolia* Desf., *Anthemis tinctoria* L. var. *tinctoria*, *Lappula barbata* (Bieb.) Gürke, and *Centaurea virgata* Lam. are diagnostic species of *Onobrychido armenae–Thymetalia lecostomi* order. The most diagnostic species of *Astragalo microcephali–Brometea tomentelli* are *Herniaria incana* Lam., *Veronica multifida* L., *Cruciata taurica* (Pallas ex Willd.) Ehrend., *Centaurea triumfettii* All., and *Anthemis cretica* L. subsp. *anatolica* (Boiss.) Grierson. *Pilosello isauricae–Marrubietum astracanici* (Cansaran et al. 2010) is found between 1400 and 1570 m. *Marrubium astracanicum* Jacq. subsp. *astracanicum, Pilosella hoppeana* (Schultes) C.H. & F.W.

Schultz subsp. *isaurica* Hub.-Mor., *Onobrychis bornmuelleri* Freyn, and *Erysimum thyrsoideum* Boiss. subsp. *ponticum* (Hausskn. & Bornm.) Cullen are the diagnostic species of that association. The same syntaxonomical units with *Saponario prostratae–Astragaletum microcephali* (Cansaran et al. 2010) are found. For example, *Anthemis tinctoria* L. var. *tinctoria* and *Allium scorodoprasum* L. subsp. *rotundum* (L.) Stearn are diagnostic for of *Onobrychido armenae–Thymetalia lecostomi* order. *Polygala supina* Schreb., *Helianthemum canum* (L.) Baumg., *Ziziphora tenuior* L., *Nepeta nuda* L. var. *nuda,* and *Poa bulbosa* L. are diagnostic species of *Astragalo microcephali–Brometea tomentelli* class. *Sideritido dichotomae–Daphnetum oleoidis* association is found in subalpine region around Amasya city above 1400 m. *Daphne oleoides* Schreb. subsp. *oleoides, Sideritis dichotoma* Huter, *Thymus pubescens* Boiss & Kotschy ex Čk., *Morina persica* L. var. *decussatifolia* S. Erik & N. Demirkuş, and *Astragalus densifolius* Lam. subsp. *amasiensis* (Freyn & Bornm.) Z. Aytaç & Ekim are diagnostic species of that association. *Allium scorodoprasum* L. subsp. *rotundum* (L.) Stearn, *Centaurea virgata* Lam., and *Alyssum sibiricum* Willd. are diagnostic species of *Onobrychido armenae–Thymetalia lecostomi*. *Astragalo microcephali–Brometea tomentelli* class is characterized by several species, namely *Acantholimon acerosum* var. acerosum, *Festuca valesiaca* Schleicher ex Gaudin, *Sanguisorba minor* Scop. var. *muricata* (Spach) Briq., and *Koeleria cristata* (L.) Pers.

9.3.1 Probable Effects of Climatic Change

Ozturk et al. (2010) stated that global climate change is an integrated system of several atmospheric phenomena and their products. It has been expected that average global air temperature has increased by about 0.8 °C and this will take place by the year 2100. This phenomenon is called as "global warming." However, local climate in different geographical areas may become warmer and drier, cooler and wetter, or remain unchanged (Ozturk et al. 2010).

It has been found that oak forests in Europe have declined under conditions of global warming mainly due to oomycete root pathogen *Phytophthora cinnamomi* and the survival and degree of root disease caused by this fungus seem likely to be enhanced (Brasier and Scott 1994). Turkish forests also have a global relevance because Turkey has a unique geographical location. As a result of this, Turkey will play an important role under global climate change scenarios. First of all, Turkey may have an important phytogeographical role as a reservoir for species transfer both within Turkey and from Turkey to Europe and protect key gene pool reserves (Colak and Rotherham 2006).

Annual mean temperature will increase around 3–4 °C in the Central Black Sea Region, and reductions are expected in summer precipitation up to −10 % (ec.europa.eu/agriculture/analysis/external). After 1990's precipitation regime was changed in Black Sea Region and uniform rainfall distribution was not observed (Aslan et al. 2005).

Fig. 9.7 Steppe vegetation in inner parts of Central Black Sea Region

Forest vegetation is constantly disturbed as a result of clear-cutting and overgrazing in Central Black Sea Region (Karaer et al. 2010). As a result of the combined effects of the mentioned anthropogenic factors and global warming, the border of steppe vegetation may be extended and replaced by forest vegetation in Central Black Sea Region, especially in inner parts of the region (Fig. 9.7).

Conclusion

Central Black Sea Region has a unique vegetation because different climate types are mixed. Mediterranean, oceanic, and continental climates are seen. Mediterranean climate is seen from the sea level to 500 m. However, Mediterranean climate is also penetrated above 1000 m and along stream valleys. Oceanic climate is dominant in whole region. Continental climate is seen in inner parts. As a result of this, Euxine, Mediterranean, and steppe vegetation types are found. Different syntaxonomical units are found in associations belonging to these vegetation types. Syntaxonomical classification and interpretation of the vegetation of Central Black Sea region are too difficult. In addition to this, the vegetation of Central Black Sea Region may probably be changed due to anthropogenic factors and global warming. Owing to these factors, forest vegetation will be disturbed and the border of steppe and Mediterranean vegetation types may be extended.

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Chapter 10
Impacts of Climate Change on Georgia's Mountain Ecosystems

Dali Nikolaishvili and Lia Matchavariani

10.1 Introduction

Climate change is one of the most important problems for mankind caused by the catastrophic consequences, which could take place if the global climatic system loses its equilibrium. Georgia (as wells as Caucasus), together with other Black Sea countries, is under the impact of climate change. This is because of several environmental problems in Georgia as well as other Black Sea states such as: activation of natural disasters (flooding, avalanches, mudflows, etc.), increase of soil erosion and degradation, deforestation and desertification, a rise in the risk of extinction of relict and endemic species, reduction in biodiversity, landscape fragmentation and degradation, less attention paid towards the sustainable and nature-protection functions, reduction of agricultural productivity (Ozturk et al. 2010a). Therefore, main interest is directed at finding ways that would diminish this danger as much as possible, and avert the effects caused by environmental degradation (Ozturk et al. 1995).

According to Georgia's Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC; Elizbarashvili et al. 2000), a number of vulnerable sectors and regions have been identified, and the adaptation of critical systems and economy sectors is a priority for the countries in the Caucasus. One of the most vulnerable to climate change ecosystems in Georgia is the high mountainous zone (Kvemo Svaneti)—which has been identified as a vulnerable area to various degradative forces and disastrous weather events significantly enhanced by global warming (landslides, mud torrents, floods, and snow avalanches),

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intensified land erosions, damaging agricultural losses, and decrease in forests, etc. Mountains are the dominant geographic feature of Georgia. The Caucasian mountain ranges in the country run parallel to the Greater Caucasus range, which are connected by the Likhi range, dividing the country into western (with subtropical humid climate) and eastern (with temperate continental climate) halves. The Southern Georgian Volcanic Highland lies next to the south of Lesser Caucasus Mountains.

One of the most important problems of modern geography is to determine natural potential and trends of the landscapes. This problem needs analysis of many landscape indicators, one of these being landscape and biodiversity. Landscape and biodiversity in Georgia are higher in mountain zones than in the plains. The most diversity is on the low-mountain forest landscapes of East Georgia (located on the southern slopes of Greater Caucasus), which is completely under the influence of natural and anthropogenic factors.

Landscape diversity is high in those landscapes, which are widespread, occupy large hypsometrical zones, and are located between landscapes with different humidities. These are also characterized by different anthropogenic transformations as well as the differences between aspects of slopes.

Against the background of continuous increasing anthropogenic pressures on the natural ecosystems, global climate changes are leading towards the fragmentation of landscapes, deforestation, and desertification; deepening of the uneven distribution of water resources, decrease in productivity of many ecosystems and crops, reduction of the area suitable for agricultural purposes and eventually, to the degradation of the cryosphere and landscape as a whole. It is, therefore, very important to identify the level of responsiveness of landscapes towards the natural and anthropogenic forces.

Glaciers are the best indicators for climate change. Late-twentieth-century changes in glacier extent in the Caucasus Mountains have revealed that average speed of glaciers has retreated during 15 years to 8 m/year; maximum speed of retreat has been 38 m/year (Elizbarashvili et al. 2000). The increase in the number of glaciers is connected with their deviation and partitions, as a result of thawing. The relative uprising of sea level on the eastern coast of the Black Sea has been due to extensive melting of glaciers in the mountainous regions, provoking flooding processes in the lowland territories (Matchavariani et al. 2011).

In view of the facts cited above, the importance of developing scientific methodology to evaluate the sensitivity of the landscapes of Georgia to the climatic changes and trends taking place in the landscapes is very important and one of the urgent problems. It is necessary to plan and realize the measures of both ecological and socioeconomic systems towards their adaptation in the event of more effective climatic changes. The main goal here is to evaluate the impact of the climatic change on the mountain landscapes of Georgia, and identify the landscapes characterized by high sensitivity and facing threats.

10.2 Study Area

Georgia is a country with diverse natural and, also, climatic conditions, which is expressed in the high level of bio- and landscape diversity. The main reasons for this are an interchange of lowlands and mountains. The country is also located on the conjunction of moderate and subtropical climatic belts, characterized by diverse natural and climatic conditions. In this regard, an important role played on the biodiversity are geological factors (distribution of silicate, limestone, and volcanic rocks), and also climatic changes during the Quaternary period, which resulted in a tertiary flora still surviving in the Colchic foothills of West Georgia. Georgia, in general, is characterized by the existence of humid, extra humid, semihumid, semiarid, and arid ecosystems with swamp plants, deciduous and coniferous forests, steppes, thorny plants, subalpine, and alpine meadows, etc. The country has almost every climatic zone, except for savannas, tropical forests, and deserts. These are covered by a plant diversity composed of 300 species belonging to 71 genera on 14 types and 23 subtypes of landscapes (Beruchashvili 1998). So, more than three types of landscapes cover every 10,000 km^2 area. These are distinguished by virgin forests occupying almost 10 % of total territory of the country (Beruchashvili 1995). Georgia is included among those few countries, which are characterized by diversity—having both the natural and anthropogenic diversity (Gobedjishvili and Kotliakov 2006). Latter defines the fragmentation of landscapes, formation of agricultural lands, urban areas, degraded ecosystems, and polluted territories.

There are many studies dedicated to the impact of climate change in Georgia (Lurie 2002; Neidze 2004; Nikolaishvili 2009; Beritashvili et al. 2010; Matchavariani et al. 2011; Nikolaishvili and Demetrashvili 2011); however, not much has been published on the impacts on individual landscapes. No methodological fundamentals explain the mosaic nature of climatic change impacts on the mountain landscapes of Georgia. This is a very important question related to the mountain landscapes. Considering that the network of hydro-meteorological observations is scarce in the mountains, the importance of the problems related to this topic and necessity for its real evaluation fully comes to the forefront.

The impact of the climate change on different landscapes of Georgia has not been studied in depth; as such, no relevant methodology has been developed. A landscape approach allows identifying the mosaic nature in question and reasons for the same. A landscape, like a "mirror," reflects all the properties and trends in the change of the state of environment associated with the climatic change. The main thing is to find out the mechanism allowing identifying the expected trends, particularly the areas at risk, and, most importantly, conditions to avoid or mitigate the threats.

The specificity of this study is associated with two important aspects: First, the information has been accomplished at the level of the landscape species, with basic weather station/post selected individually for each of these. The most important thing is that such an approach has allowed identifying the current changes in the landscape. It is clear that the development of the new methodological basics of the spatial and time model of the climate change and inventory of the landscape ethology need to be based on an approved approach—identification of daily states (geo-states) of the natural-territorial complexes based on the concept of spatial and time analysis and synthesis developed by the earlier workers (Beruchashvili 1986). On the one hand, this means specifying the geo-states and annual dynamics of the natural-territorial complexes based on the basic parameters (daily air temperatures, presence of atmospheric precipitations, and height of the snow cover; approved already); on the other hand, it implies the engagement of the so-called extra parameters (amount of atmospheric precipitations, wind velocity, relative humidity, etc.; duration, reoccurrence, alternation and transition trajectories of geo-states, behavior of the natural-territorial complexes). This means that in order to specify the resistance of the landscape to the climatic change, and its current trends, the geo-states of the natural-territorial complexes should be identified in greater detail. Such an approach will make it possible to fill the gap with the structural aspect of the concept of spatial and time analysis and synthesis of the natural-territorial complexes.

This type of investigation requires 1:1,000,000- and 1:500,000-scale landscape maps form the cartographic basis of the study (Beruchashvili 1998, 2000), with species and type of vertical structure of the natural-territorial complexes as the least landscape classification unit. So we have used here the results of the field and semistationary studies carried out by the scientific research laboratory during 1977–2005 in order to study the environmental aspects, by the Transport studies Unit (Tbilisi State University) aerospace methods, for different time intervals in different landscapes of Georgia. The results of studies carried out for many years, at Martkopi station, were also evaluated. Various reference books (Nikolaishvili and Demetrashvili 2011) on climate studies, giving the climatic features of the weather stations/posts, were also used here.

10.3 Research Methods and Initial Data

10.3.1 Landscape-Forming Oro-Climatic Factors

There are many factors influencing the formation of the landscapes of Georgia, such as (a) location (latitudinal location and elevation of the area), (b) atmospheric circulation and orohydrographic barriers, and (c) nature of the underlying surface.

Georgia is located between 41° North latitude and 43° East longitude, and, as a consequence, the territory of the country receives enough source of solar energy. Its location at the edge of the subtropical and moderate climatic belts results in the diversified landscapes, which is also promoted by the great intervals of the absolute altitude (over 5 km).

Among oro-climatic barriers, Greater Caucasus range—extending approximately about 900-km length in Georgia—plays the most important role in the formation of various climates and different landscapes, separating the north slopes and subtropical climatic belts from the remaining parts. This range blocks the penetration of cold north air masses. However, the cold air masses, sometimes, penetrate the country through some river gorges of the Great Caucasus, but their influence is limited. If no such orographic barrier existed, the climate of Georgia would be colder, being most notable, in the cold season of the year.

Other important oro-climatic barriers are Likhi and Arsiani mountains, serving as the watersheds of Black and Caspian Seas, extending from the Greater Caucasus to Lesser Caucasus. The Greater Caucasus also blocks the penetration of western humid air masses, creating two parts in the country: The humid western part, mainly, with forest both on the plain and mountainous areas, and, the relatively dry, eastern part, mainly, with arid woodlands, steppes, semidesert vegetation on the plain, and with forests in the mountains. Its influence makes the difference between the slopes inverted toward the Black Sea and the inner part of country (Beruchashvili 1993). The border between the humid and dry subtropics runs across the crest of Likhi and Arsiani ridges.

West and East Georgia are characterized by, more or less, clearly different physical geographical peculiarities of climate formation, observed in the different circular processes of the atmosphere. As the air masses penetrate the territory of Georgia from the west, the air temperature decreases, the weather is cloudy and wet, and abundant atmospheric precipitation is observed particularly in West Georgia. The same air masses, while moving across Likhi ridge towards East Georgia, lose much of the humidity (CEO 2002).

Thus, humid and semihumid landscapes are mainly represented in the western part of Georgia and semihumid and semiarid distributed between 800 and 2000 m above sea level (asl). The *Javakheti volcanic highland* in the south is dry, where semiarid and arid landscapes are observed, protecting a significant part of Georgia from the penetration of hot and dry south air masses.

Secondary oro-climatic barriers too are important landscape-forming factors, which are responsible for the rain-shadow effect. This effect contributes to both the relative humidity of the windward slopes, and the humidity, which dominates on the opposite side, interior slopes of ranges, and adjacent depressions.

10.3.2 Landscape Diversity of Mountains of Georgia

The landscape spectrum on the territory of Georgia is quite diversified with apparent peculiarities of territorial distribution. Mountain landscapes are found throughout the country within the Great Caucasus and Lesser Caucasus, and, also, within Javakheti volcanic plateau, occupying more than 51,000 km^2 which makes up more than 73 % of the whole territory of Georgia. There are 150 species belonging to 71 genera on 14 types and 21 subtypes of landscapes (Beruchashvili 2000). The mountain landscapes are represented by 8 types, 15 subtypes, and 48 pieces of landscapes (Fig. 10.1).

These landscapes are:

Mountainous subtropical semiarid (type)

- Steppes, "shibliak," open woodlands (subtype)—2 genera

  Mountainous subtropical arid (types)

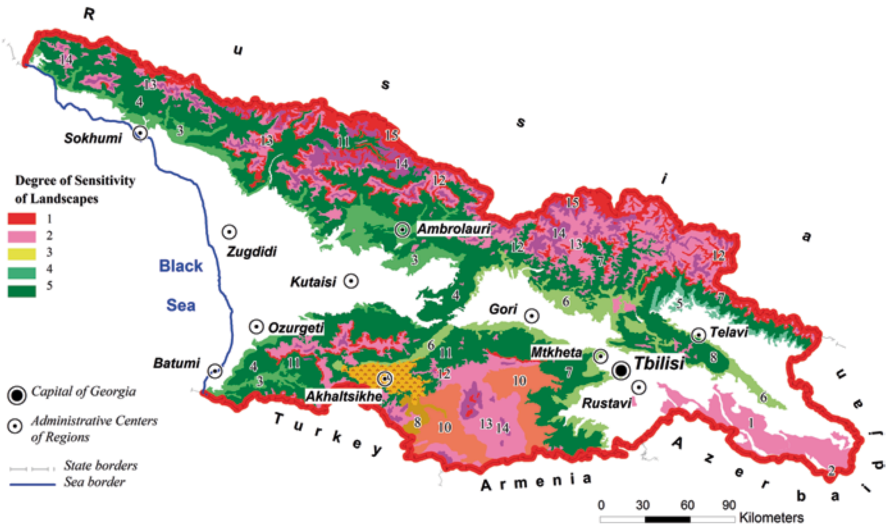

Fig. 10.1 Distribution mountain landscapes of Georgia (explanation in the text)

- Semidesert and Desert (subtype)—1 genera
  Mountainous thermo-moderate humid landscapes (types)
- Low-mountain forests Colchic (subtype)—5 genera
- Middle-mountain Colchic landscapes with beech forests, evergreen understory (subtype)—6 genera
- Low-mountain Iberian Forest (subtype)—1 genera
- Transitional to semihumid low-mountain forests (subtype)—5 genera
- Middle mountain Iberian with prevalence of beech forests (subtype)—3 genera
  Thermo-moderate semihumid landscapes (types)
- Middle-mountain landscapes with meadow–steppes, dry open woodlands (subtype)—1 genera
  Mountainous thermo-moderate semiarid (type)
- Transitional to Thermo-moderate mountainous depression with steppes, meadow-steppes, “frigana” and “shibliak” (subtype)—1 genera
- Highland volcanic plateau landscapes with steppes and meadows-steppes—1 genera
  Mountainous cold-moderate landscapes (types)
- Middle-mountain dark coniferous (spruce, fir tree) forest (subtype)—3 genera
- Upper mountainous pine and birch forest (subtype)—5 genera
  High-mountain meadow landscapes (types)
- High mountain subalpine landscapes with elfin forests, shrubs, and meadows (subtype)—6 genera
- High mountain alpine landscapes with meadows, alpine mats (subtype)—4 genera
- High mountainous subnival landscapes with mosses, lichens, and cliffs (subtype)—2 genera

High-mountain glacial–nival Landscapes (types, subtypes)—1 genera

The most diverse among the landscapes of Georgia are the low-mountain forest landscapes resulting from the natural and anthropogenic factors. These landscapes are located between the piedmont and middle-mountain forest landscapes and as a consequence, have the ecosystems typical to both landscapes. They are modified more than the middle-mountain forest landscapes located at higher hypsometric altitudes. This is the reason why the fragmentation of the low-mountain forest landscapes is greater.

The most diversified are the mountain forest landscapes in the east, spread over the southern Great Caucasus slopes, and northern slopes of the Lesser Caucasus. These landscapes are located between the piedmont semihumid and middle-mountain moderately warm humid landscapes. The result, of the near location of the piedmont semihumid landscapes, is the semihumid ecosystems spread over lower borders, and humid ecosystems spreading at the upper borders, as a result, of the near location of the middle-mountain forest landscapes. The degree of anthropogenic transformation is higher, with the low-mountain landscapes, explaining such a high degree of diversity of the landscapes here.

The middle-mountain forest landscapes are much more uniform than other landscapes. The difference between the landscape species too is clear. In particular, great diversity is observed on the middle-mountain forest landscapes spread over the northern slope of the Lesser Caucasus. The least diversified landscapes are observed along Adjara–Guria section, dominated by beech forest ecosystems with Colchic sub-forest or hemihiles. In the above-described picture of diversity, the exclusion is the lower- and middle-mountain landscapes of Great Caucasus of Kakheti, which are relatively uniform. This is because these landscapes are spread over a narrow strip with less oro-climatic barriers. The exposure difference in the territorial distribution of the natural-territorial complexes is relatively less.

The upper-mountain forest landscapes of West Georgia are more diverse. This must be due relatively to the uneven humidities on these landscapes because of the oro-climatic barriers. A certain part of the territory, of the said landscapes, is subject to the influence of the so-called rain shadows, while the other part is directly influenced by humid air masses. As a result, both, humid and semihumid natural-territorial complexes are observed here.

Most of the landscapes in Georgia are of a humid type, with 86% of the total area of the mountain landscapes belonging to this (Fig. 10.2). It incorporates 37 landscape species, i.e., most of the mountain landscapes are humid, and, as the logic suggests, it must have greater ability to adapt to the climatic change. However, on the background of the diversified natural conditions and anthropogenic impacts, the situation is much more homogenous. The semiarid and semihumid transitional landscapes occupy nearly the same areas (8 100 and 5 400 km^2, respectively) incorporating nine landscape species. As for the semihumid and arid mountain landscapes, each of them incorporate one type of landscape with the total area of only 0.5000 km^2.

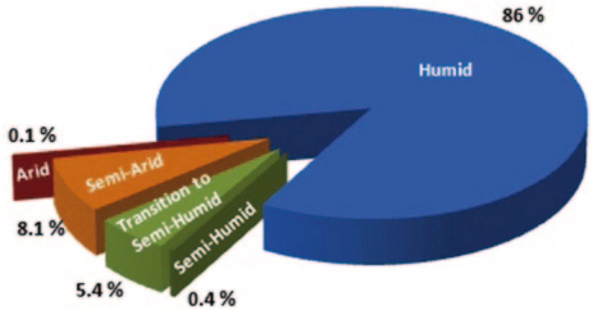

Fig. 10.2 Area of mountainous landscapes of Georgia (on the basis of humidity %)

10.3.3 Territorial Distribution of Mountain Landscapes of Georgia

The borders between the landscape units run at different hypsometric altitudes, and this is well seen not only with large but also with relatively small orographic units. The altitudinal amplitude may reach even several hundred meters. For instance, the borders of middle-mountain forest landscapes mostly run at 800 (1000)–2000 m asl (Fig. 10.3), though, quite often, they go beyond this altitudinal range. The middle-mountain forest landscapes with dominant beech forests in the river Enguri basin, in West Georgia, even go down 700 m asl. The same is true with the upper hypsometric limit of the said landscapes. This is all about the natural borders of the landscapes. On the other hand, the lower limit of the landscapes change with time due to the anthropogenic influences. In particular, the lower border of the middle-mountain forest landscapes has elevated, while their lower border have lowered.

Based on the analysis of the 1:500,000-scale landscape map of Georgia (Beruchashvili 1993), showing the types of the vertical structure of the natural-territorial complexes, the area of each landscape species can be identified. As expected, the mountain landscapes occupy the largest area making 76 % of the total area of Georgia. The landscapes in the mountains—depending on the altitudinal zoning—are distributed as follows: low-mountain landscapes occupy 3 % of the total area of the territory of Georgia, mountain basins occupy 1 %, lower-mountain landscapes 12 %, middle-mountain landscapes 24 %, upper-mountain landscapes 7 %, high-mountain subalpine landscapes 21 %, high-mountain alpine landscapes 6 %, and high-mountain subnival and nival landscapes 1 %.

High-mountain landscapes are widespread both in the West and East Georgia on the northern and southern subcrest slopes of Great Caucasus and Lesser Caucasus, and go up to 1800 (2000)—2700 (3500) m asl. In some places, they descend below this range. The middle-mountain forest and high-mountain subalpine landscapes occupy relatively larger areas in West Georgia, while lower- and upper-mountain landscapes are mostly spread in East Georgia. As for the alpine landscapes, they are almost evenly distributed—western and eastern parts of the country.

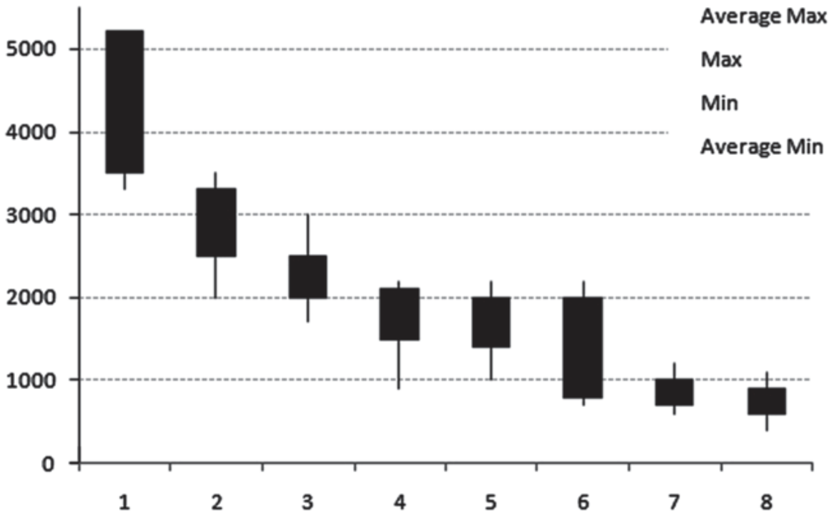

Fig. 10.3 Hypsometrical range of distribution of Georgia's mountain landscapes. *Average Max and Average Min—Average range of distribution; Max and Min—Absolute range of distribution*

10.3.4 Phytomass of Mountain Landscapes of Georgia

The phytomass of the landscapes in Georgia has been investigated by a number of workers, with more than one paper dedicated to the individual aspects of phytomass (Beruchashvili 1993; Nikolashvili 2008), considering the proportions of the total and fractional parts of phytomass, peculiarities of their spatial distribution, their relation to the physical–geographical conditions, and other landscape and geophysical indicators.

The mountain landscapes of Georgia differ much from one another in the amount of phytomass making 230 t/ha. The maximum amount of phytomass (over 500 t/ha) is typical to the middle-mountain beech-and-dark coniferous landscapes, while its minimum amount is found over the semidesert and high-mountain subnival landscapes.

A particularly wide variation in the amount of phytomass is typical on the landscapes with dominant forest natural-territorial complexes (Fig. 10.4). The reason for this is that there are forest-free natural-territorial complexes distributed on the landscapes beyond the forests. As a result, diversified modifications of the landscape transformation are seen, which, in turn, result in their different productivity. In particular, a large amount of phytomass is fixed within the original or slightly transformed natural-territorial complexes. The degraded forest massifs and secondary meadows fall much back. This is the reason why the amount of phytomass within the said landscapes varies widely. However, one thing is clear—the variability is less intense in the relatively untouched environment. For example, a wide range of variation of the amount of phytomass is typical to the lower-mountain and

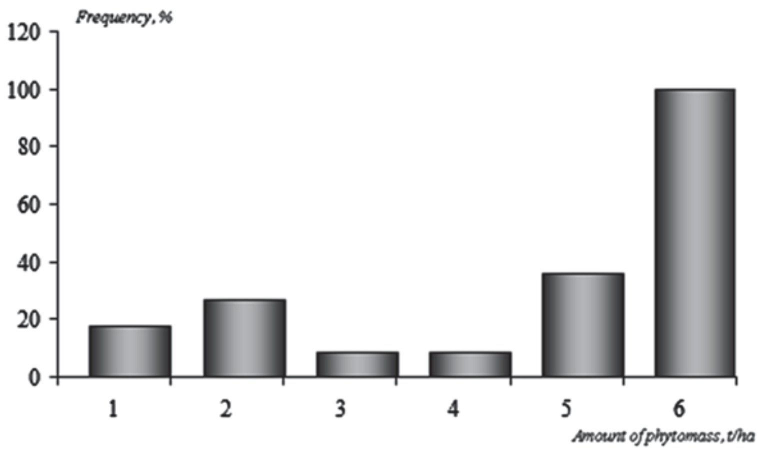

Fig. 10.4 Amount of phytomass in forest landscapes, t/ha

upper-mountain forest landscapes. The lower-mountain forest landscapes contain the natural-territorial complexes with the amount of phytomass varying from less than 50 t/ha to more than 600 t/ha (Table 10.1).

A different range of phytomass amounts is typically observed on the landscapes in West and East Georgia. Comparing the subtypes within the same type of landscape, it is clear that the diversity is more common to East Georgia due to the diversified nature of the ecosystems of East Georgia. In particular, even within the limits of the same subtype of a landscape, there are extra-humid, humid, and semihumid natural-territorial complexes distributed here. We can site middle-mountain forest landscapes distributed over the eastern part of the Lesser Caucasus where there are different types of a vertical structure of the natural-territorial complexes: deciduous shrubs of humid mesophytic macrostructure or grassy cover, deciduous shrubs of semiarid mesophytic macrostructure or grassy cover, grassy cover of a humid micro-mesostructure, grassy cover of a semi-humid or semiarid microstructure, as well as agro-complexes.

A greater amount of the phytomass in the mountain forest landscapes (over 200–300 t/ha) is usually common for the landscapes with annual atmospheric precipitation of more than 750–800 mm. A great amount of phytomass is identified in all forest landscapes of Kolkheti and Greater Caucasus of Kakheti. This is the certain optimal indicator, below which the amount of phytomass starts decreasing sharply. However, among the climatic parameters, it is not the only indicator of phytomass accumulation in the mountain forest landscapes. Two other circumstances also exist: (a) the average amount of phytomass is less at places where the annual atmospheric precipitation is close to the lower optimum, i.e., it is within the range of 700 mm. Such places are found on most of the mountain forest landscapes in East Georgia. The average amount of phytomass in lower mountains is 175–200 t/ha; it is 300 t/ha in middle mountains and 80–90 t/ha in upper mountains, while in West Georgia, the same indicator is 260, 360, and 100 t/ha, respectively, (b) greater amounts of

Table 10.1 Some physical and geographical parameters of mountain landscapes of Georgia. (see legend—Fig. 10.1)

#	Area 100 km^2	Number of landscape genera	Number of NTCs	Forest area, 1000 km^2	Amount of Phytomass, t/ha
1	4.060	3	3	1.39	<1
2	3.920	5	2	1.760	1–5
3	10.780	6	6	10.780	20–125
4	2.040	3	5	0.390	10–35
5	4.710	4	6	4.710	75–180
6	16.243	12	14	15.373	300–500 and more
7	8.110	11	17	6.068	200–300
8	2.360	1	5	2.360	20–50
Total	52.223	45	–	42.8310	–

phytomass are found at places with the maximum amount of atmospheric precipitation (500–600 mm) in the vegetation period (from May through November). This is one of the reasons for more phytomass being typical for the mountain forest landscapes of West Georgia as compared to East Georgia. The only exception is the landscape of the Great Caucasus of Kakheti.

There is a direct proportional relationship between the annual atmospheric precipitations and amount of phytomass. It is gradually leveled, in line, with the growth of these indicators. In fact, it does not matter whether the annual atmospheric precipitation is 1500 or 3000 mm. This fact can be used to explain why, virtually, there is no big difference between the amounts of phytomass over the landscapes with abundant precipitations in the western part of the Lesser Caucasus and other mountain forest landscapes in West Georgia. It is evident that the landscapes of the same subclass, type, or subtype are meant.

High-mountain landscapes, including alpine meadows and alpine mats (dominated by sedge and fescue), also subalpine rhododendron thickets and rock vegetation, are represented by herbaceous species (grazing, haymaking), which are significant summer pasturelands for sheep, livestock, and, partially, for goats. The dominant species of Mixtoherbosum-meadow and grass-meadow communities are: Brometo Agrostideta (*Bromus variegatus, Agrostida planifolia*), Deschampsiea (*Deschampsia flexuosa*), Hordeeta (*Hordeum violaceuth* and Festuceta (*Festuca ovina, F. varla, F. rupicola, F. supinae*). The dominant species of Mixtoherbosum-meadows communities are: *Betonica grandflora, Polygonum carneum, Inula orientalis*, and others (Gunia 2011; Matchavariani and Lagidze 2012).

Among grassland areas (Nakhutsrishrvili et al. 1980), the highest phytomass is character for *Festuca varia* and *Helictotrichon asiaticus* (more than 60–80 g/m^2 in the beginning of summer), also for *Carex meinshauseniana* (more than 50 g/m^2; Fig. 10.5).

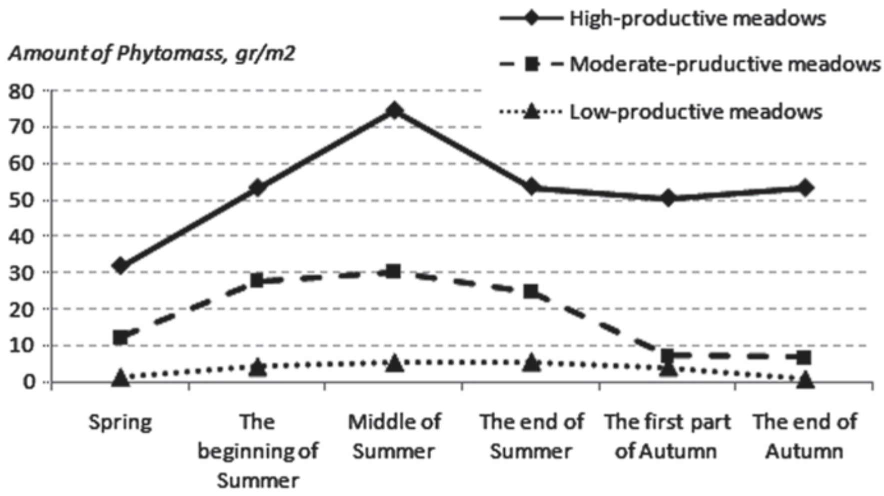

Fig. 10.5 Amount of phytomass in different periods

Overgrazing has resulted in changes in the land cover, increasing soil erosion, and decreasing productivity of soil and vegetation (Ozturk et al. 1995). These processes are determined by both natural and anthropogenic factors. So, avalanches, mudflows, and landslides are common for these landscapes. Caucasian rhododendron thickets mostly are characteristics for northern slopes of Great Caucasus and Lesser Caucasus.

Another dominant vegetation community is subalpine meadows with representatives like *Betula litwinowii, Betula raddeana, Fagus orientalis, Sorbus caucaigena, Salix,* and *Populus*. The vegetation over the cliffs and clastic grounds, much diversified and rich in endemic species, which does not form a single continuous area, but is presented in fragmented and small groups: *Saxifraga juniperifolia, Campanula beldifolia, Driba bryodes, Semecio Sosnowskyi, Nepeta supina, Veronica minuta*.

The typical representatives of the subnival landscape are: *Alopecurus glacialis, Jurinella subacaulis,* and *Delphinium caucasicum*.

The steppe vegetation spreads over high hypsometric steps across Javakheti Plateau in fragments. With its species and floristic content, it is not only similar to the mountain steppe of Southwest Asia but also shows signs of influence of the Mediterranean coastal area (Ozturk et al. 1996a, b) paleoarctic zone and biogeographical zones of Central Asia, and as a result, the relict, endemic, and other floral elements are typical in these mentioned zones.

The analysis of the field and stationary studies and data of different scientific sources (Matchavariani and Lagidze 2012) shows that the change in phyto-productivity depends on the seasons of the year and is less evident in high-mountain subalpine and alpine landscapes, but, nevertheless, it is not uniform. *Festuca varia—Carex meinshauseniana*-mixtoherbosa in the vegetation association where the deviation from the mean value is 22 % (Matchavariani and Lagidze 2012), it is spread across the high-mountain alpine landscapes and forms one of the highly productive high-mountain meadows.

The circumstances associated with the exposure difference are interesting to consider. A multiyear difference in phyto-productivity, both in West and East Georgia, is much less evident over the slopes with southern or southeastern exposure, while it is clearly evident over the slopes with northern or northwestern exposure.

10.3.5 Soil-Edaphic Conditions

Soil humidity has a great influence on the formation of types of natural-territorial complexes and accumulation of phytomass. Our studies of soil humidity are based on the analysis of the field materials, allowing us to consider the said indicator in the annual dynamics. The field materials gathered for one geo-state of the natural-territorial complex reveal that when the phytogenous structure is stabilized, it enables us to compare the different landscapes of Georgia, and identify the optimal soil humidity determining the accumulation of the given amount of phytomass. In general, the increase in the average soil humidity is followed by the increase in the amount of phytomass. It was found that the average soil humidity necessary for the large amounts of phytomass to accumulate over the mountain forest landscapes of Georgia should not be less 25–30 %. As for the landscapes of West Georgia, this indicator must be as high as 30–40 %.

An important indicator to identify the peculiarities in the territorial distribution of phytomass is the distribution of humidity across the whole-soil profile. Usually, large amounts of phytomass are detected at places with the high-soil humidity preserved not only in the upper-soil horizon but also across the soil profile. Most important is to identify the humidity of a 30-cm-thick soil layer (Nikolashvili 2008). The natural-territorial complexes with the phytomass of over 300 t/ha over the middle-mountain forest landscapes of Georgia with dominant beech forests are found at places where a 30 % isoline of soil humidity runs at a depth of 30 cm and a 20 %-soil-humidity isoline runs deeper than 80 cm. In fact, it makes no difference where the 30-cm-soil-humidity isoline runs deeper than 30 cm, as such an environment is mostly characterized by large quantities of phytomass (from 300 to 500 t/ha or more).

A similar situation is observed in the lower-mountain forest landscapes of Georgia. Here too, the degree of accumulation of large amounts of phytomass depends on the depth of a 30 % isoline of soil humidity. If in East Georgia this isoline runs deeper than 30 cm, the average amount of phytomass exceeds 200 t/ha, while it is 250–300 t/ha in West Georgia. The soil humidity exceeding 60–70 % in the 10–15-cm-thick upper-soil layer nearly does not matter.

Different peculiarities were found in the upper-mountain forest landscapes. Large amounts of phytomass are found in the landscapes of the piedmont steppe, where the soil, 30 % isoline, runs at a depth of 15–20 cm. In addition, there is another necessary condition implying that a 40 % isoline of soil humidity must not be located near the surface, but must run deeper than 15 cm minimum. Under such conditions, sparse arid forests or *sibljak* develop, where the average amount of phytomass, in less transformed on natural-territorial complexes amounting to

125–150 t/ha on average. At locations where a 30% isoline runs at the depth of approximately 15–20 cm from the surface, the amount of phytomass does not exceed 50 t/ha at any location and amounts to only 20–25 t/ha on average.

A large amount of phytomass in the upper-mountain forest landscapes is detected in case of much different values of soil humidity. It is true that here too, a 30% isoline plays a decisive role, but its location at different depths results in different amounts of phytomass in some or other natural-territorial complexes. As for the forest complexes, such an isoline runs much deeper. A large amount of phytomass is accumulated if this isoline runs deeper than 35–40 cm. In terms of stronger anthropogenic transformation, a 30% isoline runs nearer the surface, which, in turn, has influence on the amount of phytomass. A relatively larger amount of phytomass in the high-mountain meadow and meadow–shrub natural-territorial complexes is observed at locations where a 30% isoline runs at a depth of 25–30 cm.

10.3.6 Ecological Functions of Mountain Landscapes

Mountain landscapes play a significant ecological role and influence the human's living environment (Efe et al. 2012; Atalay and Efe 2010). The forest landscapes of Georgia occupy nearly 40% of the territory of the country and are the most important natural resource. These mountain landscape ecosystems play very important role in the preservation of natural habitats and protection from soil erosion. High-mountain landscapes are very important for collection of medicinal and decorative plants as well as bryophytes and mosses (Gokler and Ozturk 1989; Ozturk et al. 1991, 2010; Uysal et al. 2011). Location of balneological and ski resorts make principle impacts on the sensitive ecosystems.

The ecological function of the said landscapes can be classified into several major categories:

- An environmental protection function is an important ecological function discharged by mountain landscapes. In particular, the mountain landscapes hamper the intensity of such geodynamic processes, as landslides, mudflow currents, and snow avalanches. In this respect, middle-mountain forests as well as high-mountain subalpine and alpine landscapes are of a particular value.
- The water-balance regulation function is also much important to maintain the ecological balance in the environment. Water processes over the plains and valleys are often resulting from the physical–geographical processes taking place in the mountain landscapes, to which their original nature is preserved. In this respect, the role of high-mountain landscapes is particularly important. The impact these landscapes have on the water balance regulation is evident across all vertical landscape spectrum.
- Their function is to maintain the vegetation adapted to narrow environment. The high-mountain landscapes are the areas of such ecosystems, which are adapted to certain ecological conditions only and have low valence of distribution. These ecosystems undertake much important environmental protection function;

therefore, if the conditions of their existence change due to the climate change, they will face a threat of extinction.

- They have a function to maintain the vegetation cover of post-glacial cycles. The high-mountain landscapes are a shelter for psychrophilic plants occurring in such favorable conditions during the post-glacial cycles. If a warming trend follows due to climatic change, these plants will face extinction.
- How can we reverse this process?
- We need to maintain the forest resources.
- The conservation of water and marshy ecosystems is a must. The marshes in Georgia are mostly concentrated over Kolkheti lowland, but they are also found at high-mountain subalpine and alpine landscapes as fragments. Relatively larger and less deep fragments are found at the banks of the lakes over Javakjeti Plateau, in the upper reaches of the river Ktsia-Khrami and at other locations.
- There is a need for the establishment of ecological corridors.

10.3.7 Anthropogenic Transformation of Mountain Landscapes

In some landscapes of Georgia, the reduction of forest cover is considerable, while in some landscapes, the cover has been preserved in their original nature. Georgia is one of the countries where the large masses of pristine landscapes have been preserved fairly well, and this is particularly evident in the mountainous areas. The reduction of forest cover in the history has been significant. Many historical sources refer to great forest areas on the territory of Georgia, which are currently meadows, steppes, shrubs, forest derivatives, or settlements. This fact is proved by the names of many places, fragments of forest, presence of forest soil horizons, etc. The decisive role in the disappearance of significant woodlands in Georgia was played by the change of environmental conditions due to climate change and the anthropogenic impacts.

Identifying the degree of reduction of the forest areas and phytomass reserves in the course of history is rather a difficult task. We used a landscape approach for this purpose and compared two maps: The Map of the rehabilitated vegetation in Georgia (Gunia 2011), showing the distribution of the principal plant communities in the past, i.e., before the times, when man significantly changed the environment of Georgia. We also used the physical map (1:500,000; Beruchashvili 1998), reflecting the modern picture of the distribution and the main types of vertical structures of the natural-territorial complexes. The landscape approach is based on the idea that every plant community on the map of the rehabilitated vegetation of Georgia is to be attributed to a specific type of landscape and certain type of the vertical structure of a natural-territorial complex. This allows comparing the areas of forest landscapes and phytomass reserves in different time intervals and identifying the degree of their reduction with a single methodology.

The studies have shown that the reduction in the forest areas in Georgia has been occurring since the ancient times, and humans have played a significant role (Atlas

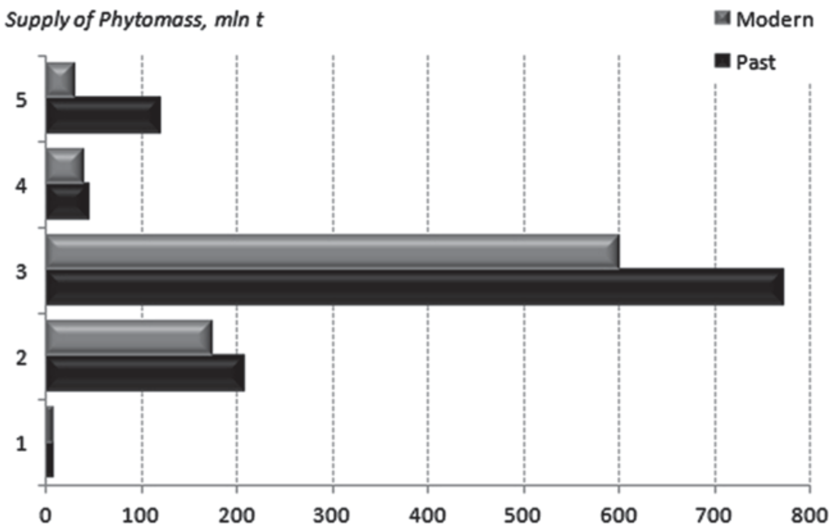

Fig. 10.6 Supply of phytomass in different mountain landscapes of Georgia

of Georgia 2012; Beritashvili et al. 2010). This corresponds to the global trend of deforestation in the same period (Ozturk et al. 1997, 1998). However, for centuries, shrinking of forest areas in Georgia is comparatively less than the same indicator at the global scale. This is quite a high indicator, if comparing this data with the degree of reduction of forest areas over the whole surface of the earth in the last 100,000 years (Georgia 2004; Beritashvili et al. 2010;Tsomaia 2010; Atlas of Georgia 2012).

The mountain landscapes of Georgia occupy large areas (46,000 km^2). They contain the largest amount of phytomass—795,300,000 t (61 % of the total phytomass reserve of Georgia; Fig. 10.6). With this indicator, the middle-forest landscapes are particularly significant, at present having accumulated 608.3 million t of phytomass, with the degree of reduction of only 14 %, while over the plain and higher-mountain landscapes, the same value is 46 and 75 %, respectively. A relatively large stock of phytomass is accumulated in West Georgia, as compared to East Georgia.

From the human historical point of view, the forest areas of Georgia have decreased by almost one third. Nearly 12000 km^2 of forest area has been destroyed. Anthropogenically, the least effected among the landscapes of Georgia are mountain landscapes, with minimum impacts observed in high-mountain subnival and nival landscapes. Similarly, middle-mountain forest landscapes have been subject to relatively less changes, as they are located in complex orographic conditions (over the steep and averagely inclined slopes).

Undisputedly, only some parts of the landscapes are subject to the anthropogenic transformations. In some cases, it occurs at the level of small morphological units, while at other times, they take place at the level of larger classification units. However, we share the view that the largest classification units of the landscapes (classes, subclasses, types, subtypes, varieties) are not subject to the anthropogenic transformation. One can only speak of full or significant transformation of some component of a landscape, for instance, the land cover at the level of the highest classification unit. The important fact of the various anthropogenic factors occurring with different intensity in different regions of Georgia and the natural systems reacting to these effects should be taken into account differently. This is why the differential change in the same landscape can be the case, what makes it difficult to group them in this regard and to fix exactly the taxonomic level, at which the anthropogenic transformation of landscapes of Georgia takes place.

At the level of morphological units, the anthropogenic transformations take place mostly and more intensely in the middle-forest landscapes of Georgia. Such landscapes occupy the largest area (56 %) of the forest's natural-territorial complexes, with 61 % of the total phytomass reserves of Georgia accumulated here. It is these landscapes covered with significant areas of pristine forests. These forest masses have been preserved owing to the complex orographic conditions hindering the expansion of settlements or economic activities, and, for many years, these forests were kept as environmental protection and environmental restoration areas, according to the effective Forest Code. All were assigned to the category I, with the commercial and clear-cutting of forests extremely limited. This Code regulated the questions of use, protection and restoration, and state registration of forest resources and questions of responsibility for violating the forest legislation, and included a clear indication of the most forests of Georgia attributing to the first category, i.e., assigning the forests an environmental protection function. This meant that any commercial cut down of forests was forbidden, and only selective sanitary cut down (of old, withered, or hollow trees) was allowed. Clear-cutting and thinning out the forests over the slopes was totally forbidden, only use was limited, and annual amount of growth of timber never caused any reduction in the forest areas. The area of exploitation of forests was only 10000 ha with the total timber reserve of 1 million m^3 (Beruchashvili 1979). Modern legislative standards envisage the same restrictions and permits. Accordingly, the average mountain forest landscapes, as compared to the high-mountain subalpine or alpine landscapes, have their original appearance preserved better to date.

The situation is quite different with lower-mountain forest landscapes of Georgia. In some cases, the anthropogenic transformation of the phytogenous structure of the landscapes is expressed at the level of morphological units, while other times, it is expressed at the level of the landscape species. The latter is especially evident in the settled mountain basins, in the lower-mountain forest landscapes of the eastern part of the Greater and Lesser Caucasus (with the exception of the Great Caucasus of Kakheti). Here, the natural vegetation consists of hornbeam, oak, hornbeam, oak-oriental hornbeam, oak, and, in particular, beech forests, with their area significantly reduced, while owing to the changed natural-territorial complexes, it accounts for 80–85 % of the total area of these landscapes.

The high-mountain subalpine or alpine landscapes are subject to intense grazing. Particularly negative consequences are observed with the destruction of a grass cover in both the subalpine and alpine landscapes as well as in the steppes of the plains and foothills, which are used as pastures and hayfields. Stopping the use of winter pastures in Dagestan (Kizlyar steppe, Russia) has caused, on the one hand, the decrease of the smalls, and on the other hand, an overload of the pastures on the territory of Georgia, which, in turn, contributed to the acceleration of aridity and resulted in the increased land area subject to desertification, particularly in East Georgia.

Depending on the degree of anthropogenic transformation, the landscapes of Georgia are grouped in six categories (Nikolashvili 2008), with no categories of strongly or significantly transformed landscapes found in the mountains. *Moderately altered landscapes* with low population density (50–100 people/km^2), 20–40% of the agricultural plots of fields of the total landscape area and a small number of industrial enterprises mostly occupy lower-mountain forest landscapes. *Slightly altered landscapes* with very low population density (less than 50 people/km^2), less than 20% of the total agricultural plots of field of the total landscape area and small number of industrial enterprises incorporate semiarid and arid landscapes of east Georgia, as well as middle-forest and higher-mountain forest landscapes of Georgia. This category also incorporates much of the high-mountainous subalpine and alpine landscapes. *Virtually unchanged landscapes* occupy only 6% of the total area of the territory of Georgia. These include high-mountain subnival and nival landscapes.

10.3.8 Dynamics of Air Temperature

The analysis of many-year data has evidenced significant changes in air temperature expressed differently in different landscapes of Georgia, including high-mountain ecosystems. Such a difference occurs depending on average multi-year air temperature, maximum temperature, duration of cold and warm periods, and other parameters. It should be mentioned that trend of change of annual average air temperature is very complex and diverse especially in high-mountain ecosystems. These differences are determined by inequalities of high-mountain ecosystems of western and eastern parts of Great Caucasus and Lesser Caucasus, also Javakheti Volcanic Plateau.

It should be noted that the change in air temperature is not a one-sided trend. The multiyear analysis of the data shows that the average multiyear air temperature grow or reduce at different times, but the general trend is anyway clear. In particular, this parameter grew by 0.2 °C during the years 1990–2006.

The mountain landscapes are characterized by cold and continuous winter and cool, humid, and short summer. The annual average temperature is −8 to −10 °C and less. During the period from 1955 to 2008, in Georgia, the annual average air temperature increased by 0.2–0.6 °C (Elizbarashvili et al. 2000). Obviously, the increasing trend is evident in both East and West Georgia. Due to the various trends in different landscapes, the real situation must be characterized in detail. Data analysis shows a relatively increasing trend in mountainous, subtropical, semiarid, and arid landscapes extending up to a height of 900–1000 m asl in extreme southeast part of Georgia with open woodland, steppe, and poly-desert vegetation. This is a characteristic found mostly during the cold period of the year. On the contrary, in the warm period of the year, there is either a slight decrease in the temperature or no change at all. So, it can be mentioned that the climate becomes more continental in mountainous, subtropical, semiarid, and arid landscapes.

To some extent, a different situation is observed in mountainous landscapes of West Georgia. Here, the abovementioned trend is less expressed, but not unimportant. In recent years, here, the average annual temperature has increased by 0.2–0.3 °C.

In high-mountain landscapes with alpine and subalpine thickets, shrubs, and meadows, at altitudes above 2000–2500 m, we come across temperate and humid climate with cool summer and cold winter. In July, the average temperature is about 16.7 °C, with an absolute minimum between −30 and −35 °C. In recent years, the average annual air temperature in these landscapes has increased by 0.4 °C. The duration of plant vegetation continues from the beginning of April to the end of September. The lowest average temperate is fixed in December and January (−3, −5 °C), absolute temperature is −25 or −28 °C.

In mountainous thermo-moderate, semihumid, and semiarid landscapes of South Georgia, in fact, the average air temperature in mountainous thermo-moderate, semihumid, and semiarid landscapes of South Georgia has not changed, but decreased slightly in recent decades. This is a clear indication of the minor outcome of the impact of the climate change on the temperature regime over the given landscapes.

10.3.9 Dynamics of Precipitation

It is considered that the change of atmospheric precipitations will be more important than that of air temperature in Georgia. Therefore, in this respect, the evaluation of this indicator is particularly important. In almost every landscape of Georgia, the annual precipitation is varying according to different natural conditions. The differences are not connected to the distance from the sea, but the increase in altitude, getting some territory under a rain shadow, local peculiarities of landforms, etc. Besides some exceptions, the gradual decrease of atmospheric precipitations and humidity takes place from west to east, in compliance with the distances from the Black Sea. So, depending on the altitude and remoteness from the Black Sea, three district/subdistrict of climate are represented. The mountainous landscapes of West Georgia belong to the humid subtropical climatic district, while the mountainous landscapes of East Georgia are a part of moderate humid subtropical climatic district. In accordance with the annual precipitations, landscape area of West Georgia accounts for more than 1600 mm. The exceptions are the mountainous depressions, situated under the rain shadow, with amount of precipitation less than 900–1000 mm. The annual precipitation of mountainous landscapes of East Georgia is rather low and is less than 1200–1400 mm (with some exceptions). The mountainous landscapes of South Georgia enter in the composition of moderate humid subtropical climatic district as a transitional subdistrict to the dry subtropical climate. Here, annual precipitation is fluctuating between 450–700 mm (Atlas of Georgia 2012).

In the low-mountain and middle-mountain forest landscapes of West Georgia, a slight increase in atmospheric precipitation takes place, which is far less than in the Colchic valley. As for the low-mountain and middle-mountain forest landscapes of East Georgia, mostly a decreasing trend in the precipitation is characteristic.

Unlike air temperature, the impact of the climate change on the landscapes in South Georgia is much stronger. The period from 1970–1980s to 2006 was marked with the trend of reducing atmospheric precipitations making annual 8 mm on average. Since 1990, this trend has remained unchanged, but the winter precipitations have increased, while the precipitations in other seasons have reduced (Beritashvili et al. 2010). This evidences that the trend of reduction of atmospheric precipitations in the vegetation period will have a much negative impact on the bio-productivity of the plants.

There are evident differences according to separate monthly average indicators. In particular, the identical trends of precipitation are not a characteristic of every month of the year. Besides, the amount of days with short and abundant precipitations has increased. This regime takes place in both East and West Georgia and makes good preconditions for formation of natural catastrophes such as floods, flash floods, mudflows, and landslides.

10.3.10 Dynamics of Droughts

One of the expressive parameter of climate change is duration and intensity of drought. But it is especially a character for the plain landscapes of East Georgia with negative influence on the productivity of vegetation, agriculture and pastures, amount of water resources, and soil productivity. Due to intensive anthropogenic pressure, timber logging, and overgrazing, as in other parts of the Black Sea region (Ozturk et al. 1997, 1998, 2010), certain places of these landscapes are degraded. This phenomenon is less characteristic for mountainous landscapes of Georgia, but it cannot be excluded. In recent years, the droughts have occurred in mountainous thermo-moderate, semihumid, and semiarid landscapes with open woodlands, shrubs, steppe and semidesert vegetation, which is stretched in southeastern part of Georgia. During 1952–2011, the duration of droughts has increased. In comparison to 1969–75 and 1998–2011,we can see that the amount of drought days has almost doubled, making a serious problem for summer pastures.

It is assumed that a drought period of less than 20 days in east Georgia (with the atmospheric precipitations not exceeding 5 mm, maximum air temperature of 28 °C and average daily humidity of 50 %; Elizbarashvili et al. 2000) has no destructive impact on agricultural crops. Therefore, the conditions of more than 20 days were analyzed, and the analysis of the meteorological data evidences evaluated. The number of such days has grown both generally and with almost all landscapes considered above.

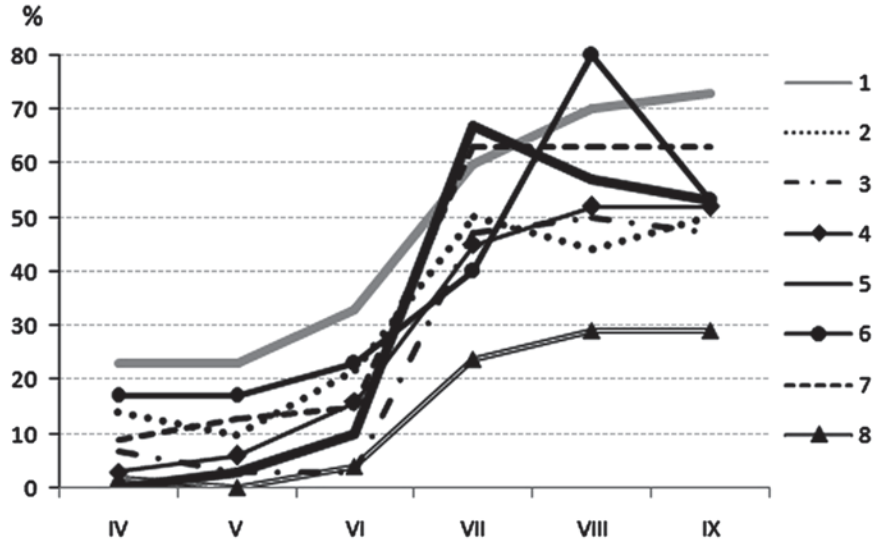

Fig. 10.7 Repetition of droughts according to months. *Landscapes genera*: *1* Low mountain arid-denudational landscapes with "shibliak," partially steppes and "phrygana" (extreme southeast part of Georgia); *2* Low-mountain erosional–denudational landscapes with hornbeam-oak, partially with chestnut forest (Kakhetian Great Caucasus); *3* Low-mountain erosional–denudational landscapes wich oak and hornbeam-oak forest (Lesser Caucasus); *4* Low-mountain erosional–denudational landscape with hornbeam-oak (*Carpinus orientalis*) and oak forests and "shibliak" (Great Caucasus); *5* Low-mountain erosional–accumulativr landscapes with hornbeam-oak (*Quercus iberica*), oak-pine and pine (*Pinus caucasica*), partially with "shibliak" (Bordjomi valley); *6* Middle-mountain erozional-denudational landscapes with beech, partially pine (*Pinus caucasica*) forest; *7* Mountainous depression denudational–erosional landscapes with steppes, "frigana," "shibliak," partially mountainous semidesert vegetation (Akhaltsikhe depression); *8* Highland volcanic plateau landscapes with steppes and meadows–steppes (Javakheti volcanic plateau).

Frequency of droughts differs much in different areas of Georgia. Dry months last from 1 to 6 months. The duration of dry months varies greatly in different regions of Georgia (Varazanashvili and Elizbarashvili 2008; Begalishvili et al. 2009).

Despite the differences, one common peculiarity comes to the forefront during the observations in 1965–2005. In particular, the reoccurrence of droughts increases in the second half of the vegetation period, from the second half of June (Fig. 10.7). The least reoccurrence of droughts is fixed over Javakheti Volcanic Plateaus, while the highest indicator is fixed with semihumid and semiarid landscapes of extreme southwestern part of East Georgia. So, likelihood of droughts is mostly expected from July to September and continues during 3 months.

Droughts are rarer, but, nevertheless, must be considered in the mountain basins of West Georgia. In terms of little atmospheric precipitations, the droughts reduce the bio-productivity of agricultural crops and cause certain problems for intensely cultivated agricultural lands and agriculture generally.

10.3.11 Dynamics of Winds

The wind intensity and direction on the territory of Georgia is associated with the impact of the western branch of Siberian anticyclone resulting in high frequency of strong eastern winds in West Georgia and dominating northwestern winds in East Georgia in terms of the Black Sea high pressure. The average wind velocity reaches its maximum in subnival and nival belts of the high-mountainous zone, across Likhi Ridge, in the crest zone of Samsari and Javakheti ridges.

Many-year studies evidence that in the cold period, the frequency of the impact of arctic anticyclone has decreased by 25–33 % in the twentieth century, a deviation from its mean value what must have been followed by intensified west processes (Beritashvili et al. 2010).

10.3.12 Dynamics of Geo-Conditions

The studies on the natural-territorial complexes is much important in predicting their dynamics. If a change in the physical–geographic parameters, including landscape–geophysical parameters in different time intervals is fixed, one can consider the expected trends developing in the natural-territorial complexes, and their reaction to some or other natural or anthropogenic impacts.

The study of the dynamics of the natural-territorial complexes is based on the analysis of many-year average data of meteorological parameters, with average daily air temperature, amount of atmospheric precipitations, strength of a snow cover, etc., being the most important ones. Based on these parameters, the changes in the vertical structure (phytogenic, nival) of the natural-territorial complexes are identified. In order to study the dynamics of the states of all landscapes of Georgia, first of all, it is necessary to link the weather stations and posts to the landscapes. This can be easily done based on the geoinformation systems.

During the said study, it is important to fix not only the average many-year dynamics of the states of the natural-territorial complexes but also their dynamics in different years. This would allow identifying the trends developed in the natural-territorial complexes and answer all the questions having constructive importance—the activation of which natural or natural-anthropogenic processes (climate warming, desertification) does it evidence? In which landscapes are these processes most clear and which landscapes face the threat of basic changes? How much close are the recent dynamics of the states of the natural-territorial complexes to the average many-year dynamics, or how much do they deviate from it? As a result (based on the concepts method), the kinds of expected changes, depending on the landscape–geophysical properties (amount of geo-masses, strength and complexity of a vertical structure), can be identified. This, in the final run, will allow identifying the trends of changes of the resource potential of the landscapes and making forecasts.

The landscapes of Georgia differ with their set of geo-states and frequency of their reoccurrence. There are approximately 25 types of geo-states of landscapes in the country, with 13 of them considered as dominant, as they occur annually in most of the landscapes. The longest is the stabilization of the winter structure, followed by the geo-states of stabilization of summer phytogenous structure.

As the geo-states change, the soil productive moisture and consequently, the process of accumulation of phyto-resources of the plants changes. The interval of change of soil productive moisture is quite long depending on the landscapes, and such a change is observed even in the period of establishment of the same geo-state. This is associated with the duration of the current geo-state, or to be more exact, how long it has been from its establishment. If humid geo-states last for several days (in the first case) or several weeks (in the second case), the productive moisture is quite high. This means that there are conditions established favorable for developing phyto-resources. As the coincidence of pluvial geo-states grows, the indicator of productive geo-states grows and reaches high values in the upper-soil layer. As for the geo-state of the winter nival structure, during it the amount of soil productive humidity is low.

The amount of phytomass in the area with the meadow–steppes, steppes, and sparse arid forests of East Georgia (over the inclined slopes) varies in quite large limits: In terms of humid microthermal geo-states, its average amount is 20–120 g/m^2, while in case of humid geo-state of complication of a phytogenous structure, it is 120–160 g/m^2. It is in terms of the two geo-states when the high value of bio-productivity is fixed. If the trend of reduction of the duration of these geo-states is observed at the expense of semiarid or arid growth, then we must assume that this process will be less intense. Consequently, the trend of reduction of bio-productivity is expected in the mentioned landscapes. If considering that a large area of the said landscapes is occupied by agricultural plots with plant growing (grain growing, fruit growing, vine growing) as a dominant branch, it will become clear how much it may hamper the economic development of the country.

A similar trend is observed in the high-mountain subalpine landscapes of East Georgia with meadow vegetation. This trend is particularly evident over the slopes of a southern exposition and in terms of significant anthropogenic impact. In particular, phytomasses originate and stabilize as the humid geo-states (nine types of them). Maximum phytomass (450–550 g/cm^2) is observed during the geo-states of summer phytogenous stabilization with their duration characterized by slightly expressed increasing dynamics. At a single glance, this must be the evidence of the conditions favorable for phyto-formation; however, if considering that the duration of simplification of humid phytogenous structure is increased and duration of pluvial states is reduced, it becomes clear that the process of phyto-origination in these landscapes will be relatively "hampered."

10.3.13 Evaluation of Landscape Sensitivity to Climate Change and Classification

A certain part of Georgia occupies an arid or semiarid zone. If considering the landscapes of Georgia on the background of the Caucasus, we will see that aridity is the least common feature of our country. However, this does not mean that there are no

Table 10.2 Classification of landscapes according to sensitivity to climate change

Degree of sensitivity	Number of landscapes genera	Number of types of NTCs	Area (1000 km^2)	Supply of phytomas (million tons)
Very high sensitive	8	16	6.740	8.1
High sensitive	17	22	21.513	72.3
Moderate sensitive	5	12	3.248	40.4
Low sensitive	5	13	4.872	166.9
Very low sensitive	13	14	15.850	323.9
Total	48	–	51.223	3526.7

problems of droughts or aridization in Georgia. As the scientists think, the natural factors promoting aridization on the background of global warming are intensified, and, as a result, the natural aridity in the Caucasus (including Georgia) has increased. This is particularly obvious in the arid and semiarid zones of the country. However, the literary sources mention the appearance of different xerophilous plant species at the locations with no such species in the past (over the cliffy massifs in Ajara and Abkhazia, in a dune zone). As far back as in the 1940s, O. Yaroshenko, a researcher of the flora in the Caucasus, talked about the increased continentality of the climate over the Lesser Caucasus and Armenian Plateau, and its influence on the vegetation cover. Such areas can be considered particularly sensitive to the climate change. This is evidenced by frequent droughts taking place in recent years on the territory of Georgia.

The landscapes of Georgia can be divided into five categories: much vulnerable, vulnerable, moderately vulnerable, slightly vulnerable, and insignificantly vulnerable (Table 10.2).

The much vulnerable mountain landscapes incorporate high-mountain subnival and nival, as well as a part of the upper-mountain forest and high-mountain alpine landscapes of East Georgia. The total area of the given category is 6700 km^2 making 9.6 % of the total territory of Georgia.

The impact of the climate change on water resources is seen in many aspects; first, there is a drawback in glaciers, change in the regime of atmospheric precipitations, and change of the water balance in watercourses. The drawback of glaciers is most important. The comparison of many-year climatic indicators and topographic maps of different years has revealed the facts of drawbacks of many glaciers across the Great Caucasus.

High-mountain nival and subnival landscapes must be considered as the most sensitive to climate change. A number of scientific works (Beritashvili et al. 2010; GNC 1999; Ketskhoveli 1959) mention the fact of drawback of glaciers (Fig. 10.8). As it becomes clear, until the 1980s, a reducing trend was observed with most of the glaciers of Georgia; however, in some cases, advancement was fixed as well.

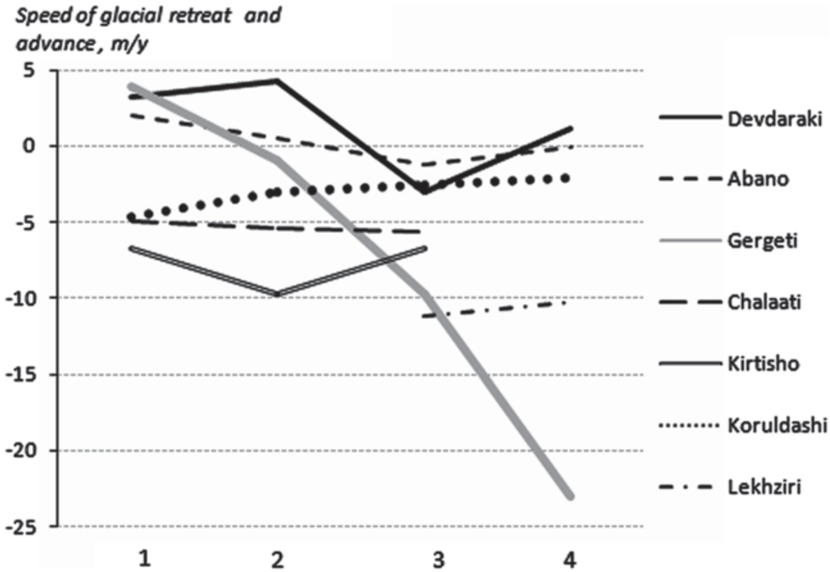

Fig. 10.8 Dynamics of glaciers of Georgia during 1965–1990. Periods: 1—1965/1966–1972/1973; 2—1973–1977/1979; 3—1977/1978–1983/1985; 1983/1985–1990

Even the advancement of Devdarak glacier has changed for drawback since 2000. Particularly, high drawback indicator was fixed with Gergeti glacier in 1985–1990 amounting to 23 m annually (Beritashvili et al. 2010).

The dynamics of nine selected glaciers at the central part of Great Caucasus during 1964–1980 has shown a retreat and advance episodes with mean rates correspondingly 6.1 and 3.4 m/year. But in the following years the absolute majority of glaciers exhibited only the retreat at the average rate of 11 m/year. Eventually, the satellite imagery data of 1985–2000 period shows that the mean retreat rate of glaciers in this region equals to about 8 m/year at the background of an annual increase of air temperature by 0.1 °C in the ablation season temperature (Beritashvili et al. 2010).

During 1965–1980, the reduction of the area of glaciers on the territory of Georgia was 17 % (from 616 to 511 km^2). Based on the analysis of the data of 1890 and 1965, the scientists assumed that the annual loss of the glaciers on the Great Caucasus was equivalent to an area of 7.5 km^2 (Neidze 2004). This process continued further. In 1900–1970, the average speed of drawback of the absolute majority of the glaciers of the Great Caucasus was 11.8 m annually (Ketskhoveli 1959; GNC 1999).

The drawback of the glaciers was much influenced by the reduced amount of winter precipitations and increased liquid precipitations. Owing to such circumstances, the glacier pulsation is activated, and mudflow currents fall down. The drawback of glaciers is followed by the origination of glacial lakes and increased areas of morena talus which, in turn, is the precondition for the origin of new areas of vegetation groups.

As for the ecosystems of subnival landscapes, their high sensitivity to the climate change is associated with very low projection coverage of the vegetation cover making 20–40 % on average, and even 5–10 % at some locations. It is known that the ecosystems of great strength and diversity are particularly resistant to the natural and anthropogenic impacts, with subalpine landscapes hard to attribute to such a category. Therefore, one can talk about the low resistance of the latter to the expected changes.

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Highly sensitive landscapes are also semihumid and semiarid landscapes spread in the extreme southeastern part of East Georgia. A significant part of these landscapes is occupied by pastures with degraded steppe vegetation due to overgrazing. The degradation of the steppe vegetation growing in the pastures is followed by the dominance of the less productive semidesert vegetation. The effective measures to mitigate the vulnerability of pastures in these regions to the climate change are the irrigation of pastures and windbreak belts preventing the soil from drying out and protecting the ground against wind erosion. As is the case with forests, the mass ploughing of pastures without arranging the windbreak belts or irrigation system will significantly boost the vulnerability of these areas to the climate change.

Due to a number of natural peculiarities (high solar radiation, abundant atmospheric precipitations, high, though not very high air temperature, duration of the vegetation period, long-lasting humid state, large amount of humus), bio-productivity of *the high-mountain subalpine and alpine landscapes* meadows is high making 5–15 t/ha on average, with the annual growth of 3–4 t/ha. However, on the background of high anthropogenic transformation and climate change, they, are the most vulnerable landscapes, and at a very high risk. This impact may be less on the northern slopes and slightly inclined slopes with the northern exposition or in terms of minor anthropogenic transformation. In this respect, the maximum impact is expected on the moderately inclined slopes with a southern or southeastern exposition, where the bio-productivity is already low.

The *vulnerable mountain landscapes* incorporate 17 landscape species occupying a vast area (21.513 000 km^2) constituting the largest part of the territory of the country (72.3 %).

Dry periods are mainly common for the landscapes located in “rain shadows” in the high-mountain zone of West Georgia. Here, as compared to other landscapes of West Georgia, the amount of annual atmospheric precipitations is less (900 mm and less), when compared to 1956–1972, the period since 1991 has been marked by the trend of increased duration and frequency of droughts. One can assume that these landscapes are highly vulnerable which will presumably reduce the phyto-resources.

These two categories of landscapes form a special group of risk, and due to moisture deficit, reoccurrence of frequent and strong winds, increased intensity of erosion, anthropogenic load, and other factors, (with some exceptions) are prone to aridization, it will have a negative impact on the bio-productivity of the natural vegetation and agricultural crops. Their high sensitivity is evidenced by the duration of daily arid and semiarid states of the natural-territorial complexes making 20% of a calendar year (Nikolaishvili 2009).

Moderately vulnerable mountain landscapes incorporate five species occupying quite a large area (3.248 000 km^2), but making only 4.7% of the total area of the country.

Slightly vulnerable mountain landscapes incorporate five species only, while *insignificantly vulnerable mountain landscapes* incorporate 13 species only (7430 km^2). Out of mountain landscapes, the middle-mountain forest landscapes of West Georgia are found here (except for a karstic landscape, where limestone substrate, due to greater infiltration of moisture and loss, is more vulnerable). This is caused by many factors, in particular, abundant atmospheric precipitations, strong vegetation cover, high values of phytomass (300–500 t/ha and more), well-preserved original nature, and low degree of anthropogenic transformation of the area. The set of the said factors result in a relatively better resistance of the landscapes to the climate change. It is true that the given landscapes have complex orographic conditions, but the factors mentioned above play a limiting role in this respect. However, it should be mentioned that in terms of a strong anthropogenic impact, the existing degree of vulnerability will decrease, and some individual sites may turn to one of the most vulnerable landscapes. Therefore, protection and conservation of the middle-mountain forest landscapes and maintaining their environmental protection function is a much important task.

10.4 Conclusion

Out of the mountain landscapes, the *middle-mountain forest landscapes with beech and beech-dark coniferous forests* are distinguished for their highest resistance to the climate change, in West Georgia particularly.

The reality cannot be judged in a one-sided manner only, as there are two opposing trends to be considered: First, the decline in the number of population and formation of post-residential areas, what, in its turn, reduces the anthropogenic load on the landscapes, and second, the deterioration of the socioeconomic situation in the country since the 1900s, having boosted the impact on the forest landscapes by the population. In the final run, the climate change may cause changes in the structure and functioning of the landscapes of Georgia. Since the forest massifs are particularly well preserved, it is in the middle-mountain forest landscapes of Georgia, where the population receives the real profit from these forest resources. Therefore, these forests, now, and in terms of the same situation in the future, are subject to a high anthropogenic pressure apparently to be the case in the future. Given the fact that the middle-mountain forest landscapes are less resistant to the anthropogenic impacts, we must assume that some of their areas may face a great risk to develop geodynamic processes. Anyway, these changes will be observed only at the level of facies or tracts, the proportion of which (of the modified morphological units) will gradually increase. Since it is difficult to "localize" even small-scale destructions of geosystems and they can spread to great distances from the source of impact, the situation is quite alarming and the management of forest resources requires special attention.

In addition, the signs of the changing forest structure and, consequently, changing functioning of the forest is expected in some forest areas. This is particularly true with the forest massifs growing over the slopes of a southern exposition, particularly when they border semihumid ecosystems. Such ecosystems will face a particular hazard at the expense of the increased air temperature and decreased atmospheric precipitations.

The natural factors promoting aridization have intensified on the background of the climate change resulting in the increased natural aridity of individual landscapes of Georgia. This is particularly obvious in the arid and semiarid zones of the country. The landscapes of Georgia are under various impacts due to the global climatic change. The landscapes in semihumid, semiarid, or arid climatic conditions face the greatest risk. As the analysis of the landscape map of Georgia evidences, they occupy 15300 km^2, making 21.9 % of the total area of the country. It is clear that most of these landscapes are located in the lowland zone of east Georgia, and they occupy 11.1 % of the total area of the country. On the other hand, certain parts of the mountain landscapes also face hazards due to the scarce and incomplete data, the study of this problem is of particular importance.

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Chapter 11
Highland Vegetation of Inner and Eastern Anatolia and the Effects of Global Warming

L. Kurt, O. Ketenoglu, G. N. Tug and F. Sekerciler

11.1 Introduction

Turkey exhibits a peculiar heterogeneous ecology in temperate zone. The altitudinal changes in climatic parameters prevent the development of trees over some elevations called as "alpine zone" depending on the regions.

In Turkey, the changes in timberline through the regions are as follows: 2100–2200 m in Mediterranean and Central Anatolian, 1900–2000 m in Aegean, 2000–2050 m in Eastern Black Sea, and 2800–2900 m in Eastern Anatolia region (Colak and Rotherham 2007; Fig. 11.1).

Alpine zones are widespread in Northern Hemisphere and many mountain ranges in Turkey have the same zone as well, Eastern Black Sea Mountains, East and West Taurus Mountains, and East Anatolian Mountains. Also, Uludag, Koroglu Mountains, Sultan Mountains, Ilgaz Mountains, Erciyes, Hasan, and Ak Mountains have alpine zones at their peaks. The highest peaks and their altitudes in Inner Anatolia are as follows: Erciyes (3917 m), Melendiz (2963 m), Hasan Mountain (3268 m); and in Eastern Anatolia are Great Agri Mountain (5137 m), Little Agri Mountain (3896 m), Tendurek Mountains (3533 m), Suphan Mountain (4058 m), Nemrut Mountain (3050 m), Kisir Mountain (2197 m), and Akbaba Mountain (3040 m; Erinc 2000).

Alpine zones exhibit very harsh conditions for the plant life. Therefore, plants of this zone have to have some adaptations to cope with these conditions. Increase in altitude results in low air pressure, which leads to changes in temperature, precipitation, and light conditions that are effective on plants survival (Atalay 2006).

The ecological conditions in alpine habitats are harsh for plant life and plants that have adaptations can survive. These harsh conditions and short vegetation period create different morphological, physiological, reproductive, and ecological characteristics on these plants (Billings 1974). Also, these conditions change in

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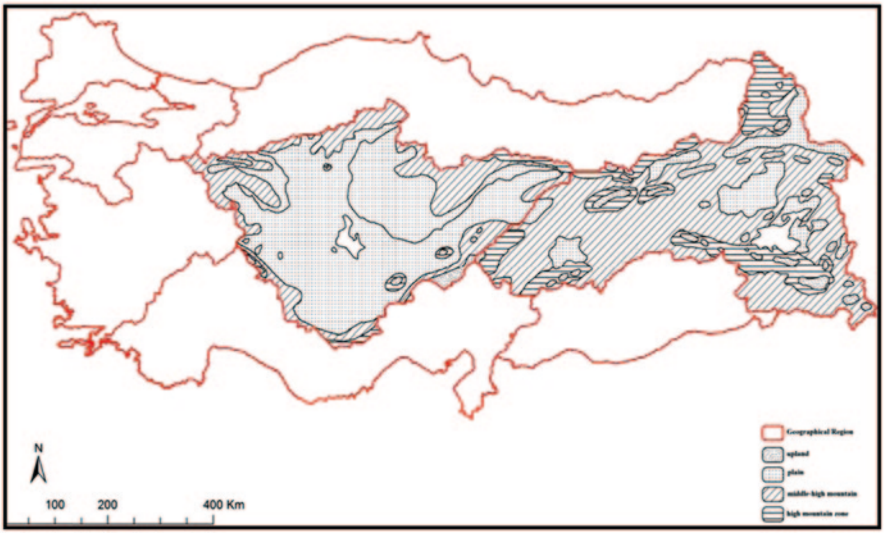

Fig. 11.1 Altitudinal changes at Central and East Anatolia regions

short distances significantly depending on the roughness, slope and microhabitats (Atay et al. 2009; Körner 2001). Perennial herbs are the most dominant life forms in alpine habitats. There are also some annual herbs, prostrate shrubs, and caulescent woody plants. Most of the species have well-developed root systems, and many of them store carbohydrates. Annual species are so small and rare. Seeds of alpine plants are dormant and require chilling to germinate (Amen 1966; Billings and Mooney 1968). Vegetative growth is fast in alpine habitats and starts when snow cover melts and soil temperature rises over 0 °C. They also have drought resistance and similar adaptations like xerophytes. Alpine plants reproduce both vegetatively and sexually. Almost all alpine plants produce flower primordia to guarantee the flowering in a short growing period (Mondoni et al. 2012). Shrubs and small trees form groups and live together to cope with the adverse effects of the environmental conditions, they form krummholz structure. Most of the species have small leaves with thick cuticle and waxy layer against transpiration. Having all these characteristics not only provides these plants to survive in these conditions but also restrict them to these vulnerable areas (Körner 1999). So destruction of the alpine habitats, which are generally considered sensitive especially against global warming, results in a threat for these plants (Pauli et al. 2003). When the conditions change, especially increase in temperature, the only thing these plants do is to migrate to higher altitudes as the lower belt plants. At one point they will reach the peak and there will be nowhere else to go to survive, their habitats getting narrower due to global warming (Parolo and Rossi 2008; Vittoz et al. 2009; Peters and Darling 1985; Ozenda and Borel 1991; Markham et al. 1993; Beniston 1994).

11.2 Phytogeographical Position of Central and Eastern Anatolian High Mountain

Turkey is situated in the intersection area of tree phytogeographical regions, Euro-Siberian (Circumboreal), Mediterranean, and Irano-Turanian. Central and Eastern Anatolian regions are considered in Irano-Turanian phytogeographical region.

Through the science of biogeography, different authors named the Irano-Turanian phytogeographical region with different names. Grisebach (1872–1884) differentiated the Irano-Turanian from its western and eastern neighbors excluding the Eurosiberian and Mediterranean areas. Although some authors included the region in Mediterranean phytogeographical region, others like Engler (1908), Rikli (1913), and Lavrenko (1950) considered some part of Central Asia as Central Asian region. Eig (1931/1932) implied that Irano-Turanian region is not completely uniform and considered the west part as "High Asia." According to some opinions and the last results from some parts of the phytogeographical region, the idea of division of the region in two parts as west and east is accepted.

Irano-Turanian region in Turkey was divided in four sectors by Zohary (1973):

1. East Anatolian High Mountains
2. Central Anatolian Sector
3. South-East Anatolian Sector
4. Mesopotamian Sector

But nowadays this division is not widely accepted. The area can be evaluated as:

a. West Asian Subregion
b. Middle Asian Subregion (Takhtajan 1986)

The West Asian Subregion was then divided in eight provinces: Mesopotamian, Central Anatolian, East Anatolian and Iran, Turanian or Aralo-Caspian, Hyrcanian, Turkmenistan, North Blucistan, and West Himalayan.

So Central and Eastern Anatolia belong to Central Anatolian and East Anatolian–Iran provinces, respectively.

11.3 Central Anatolian High Mountain Vegetation

11.3.1 Topography and Soil

Central Anatolia is a plateau peripherally surrounded by mountains such as Taurus Ranges in south and Black Sea Mountains in north. The altitude increases from west to east. Vertical timberline is 2100–2200 m in Central Anatolia. At the middle part of the karstic plateau, there are some extinct volcanos: Erciyes Mountain

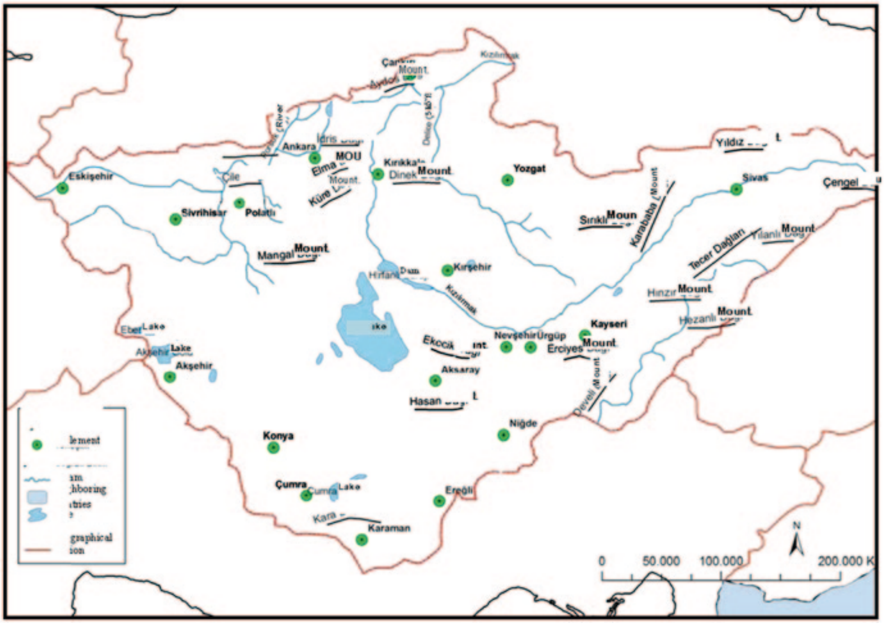

Fig. 11.2 Map of the mountains in the Central Anatolia

(3917 m), Hasan Mountain (3268 m), Melendiz Mountain (2963 m), Karadag (2271 m), and Isik Mountain (2015 m), which are the highest peaks of the area (Akman 1976; Erinc 2000; Fig. 11.2).

The mountainous parts of Nigde, southeastern part of Central Anatolia, are divided into two parts by Ecemis River from north to south. West part is composed of Nigde massif and Karadag extinct volcano, east part is composed of Aladag (Erinc 2000). Aladag ranges have some high peaks and the highest ones are Demirkazik and Kizilkaya having an altitude over 3700 m.

11.3.2 Climate

The mean minimum temperature of the coldest month is generally below 0 °C over 2000 m in Central Anatolia, which matches the mountainous and high mountain zones of Mediterranean region both climatically and floristically. The Mediterranean originated primary forest vegetation in Central Anatolia was destroyed especially by anthropogenic factors like overgrazing, reclamation, illegal logging, fires, etc., and replaced by steppe vegetation. So the Irano-Turanian originated plants took place of Mediterranean originated ones and therefore biogeographically there was a great change in the structure of vegetation (Kasapligil 1977), although the high mountainous parts of Central Anatolia have links with Mediterranean region, Irano-Turanian originated species are dominant due to the above mentioned facts.

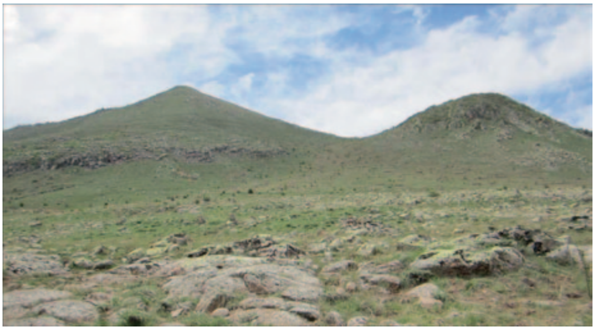

Fig. 11.3 Melendiz Mountain in the region of Central Anatolia

11.3.3 Plant Dynamics

Over the timberline, physical and chemical properties of soil results in the development of different plant communities. Although the vegetation seems uniform partially, dwarf shrubs or trees are present as well. Also, due to the ecological peculiarities, the dominant species are hemicryptophytic members of Poaceae like *Bromus tomentellus* Boiss., *Festuca valesiaca* Schleich. ex Gaudin, *Rostraria cristata* (L.) Tzvelev var. *cristata*, *Stipa lessingiana* Trin. & Rupr., *S. Holosericea* Trin., and some chamaephytes like *Astragalus angustifolius* Lam., *A. microcephalus* Willd., and *Onobrychis cornuta* (L.) Desv.

11.3.4 Vegetation

Central Anatolian high mountain vegetation phytosociologically belongs to class Astragalo-Brometea (Quezel 1973). Although this class is defined to classify high mountain écorchée grasslands of Taurus Mountains, it also includes almost all of the steppic communities in Turkey.

Although the mountainous steppe of Taurus Mountains and high mountain steppes of Central Anatolia syntaxonomically belong to the same class, their floristic structures are not same, due to the different precipitation regimes and mother rock properties. Although there are many phytosociological and floristical studies about Taurus, anti-Taurus, and North Anatolian Mountains, less is known about high mountains of Central Anatolia. Over the timberline of Erciyes Mountain, Hasan Mountain, Melendiz Mountain (Fig. 11.3), and Karadag Mountains in Central Anatolia, steppic communities dominated by chamaephytes and hemicryptophytes and xerophytic plants grow on undeveloped soils.

The cover ratios of these communities are about 40–60 % and the rest is bare and rocky area. The high mountain steppe vegetation of Central Anatolia belongs to Mediterranean high mountain zone physiognomically. The majority of plants are perennials from tertiary era. Especially species from Lamiaceae, Scrophulariaceae, Caryophyllaceae, Brassicaceae, and Boraginaceae are dominant. Many chamaephytes and perennial grasses form humid high mountain steppes, spiny cushion forming plants correspond almost half of the species with cover ratio of 20–40%.

The most dominant and major cushion forming chamaephytes of high mountain zone of Central Anatolia are *Astragalus angustifolius* Lam. subsp. *angustifolius, Acantholimon echinus* (L.) Boiss., *Onobrychis cornuta* (L.) Desv., *Minuartia juniperina* (L.) Maire & Petitm, and spiny *Astragalus* spp. The alliance Minuartion juniperino-pestalozzae Ketenoglu et al. 1996 was defined on Hacibaba Mountain around Konya province at 2000–2350 m of 20–40% slope with calcareous mother rock (Ketenoglu et al. 1996). Spiny chamaephytes are dominant in the species composition of the alliance. The dominant species within the area are *Minuartia juniperina* (L.) Maire & Petitm, *Minuartia pestalozzae* (Boiss.) Bornm, *Astragalus angustifolius* Lam. subsp. *angustifolius, Marrubium globosum* Montbret & Aucher ex Benth., *Silene pharnaceifolia* Fenzl, *Dianthus zederbaueri* Vierh., *Poa alpina* L. subsp. *fallax* F.Herm., *Centaurea mucronifera* (DC.) Wagenitz, *Veronica cuneifolia* D.Don subsp. *isaurica* P.H.Davis, *Paronychia davisii* Chaudhri.

11.4 East Anatolian High Mountain Vegetation

11.4.1 Topography and Soil

East Anatolia has a rough and mountainous topography with mean elevation of 1600–1800 m. The major mountains are Cimen, Kop, Esence, Karasu, Allahuekber at north, Mercan (Munzur), Karasu-Aras at central part, southeastern Taurus and Buzul mountains at south. Agri, Tendurek, Aladag, Suphan, and Nemrut are extinct volcanic mountains at north of Van Lake (Figs. 11.4 and 11.5; Erinc 2000).

Anatolian diagonal is a natural barrier that separates Central and East Anatolia. This diagonal is a high mountain range that divides Anatolia into two parts from Northeast to Antakya. It starts around Gumushane-Bayburt and reach to southwest anti-Taurus where it splits into two branches, one towards Amanos and the other towards Taurus Mountains. Anatolian diagonal is composed of Allahuekber, Kesis, Kargapazari, Munzur, Binboga. Tahtali and Amanos Mountains are located at the southernmost edge of this diagonal. Therefore, the southernmost distribution area of Euro-Siberian elements is the Amanos Mountains (Aytac 2010).

11.4.2 Climate

In general, East Anatolia is under the influence of semi-continental climate. Due to continentality, precipitations concentrated in summer months. So the vegetative development at grasslands reaches maximum at summer months. Therefore, high mountain areas of eastern Anatolia are dominated by damp grasslands.

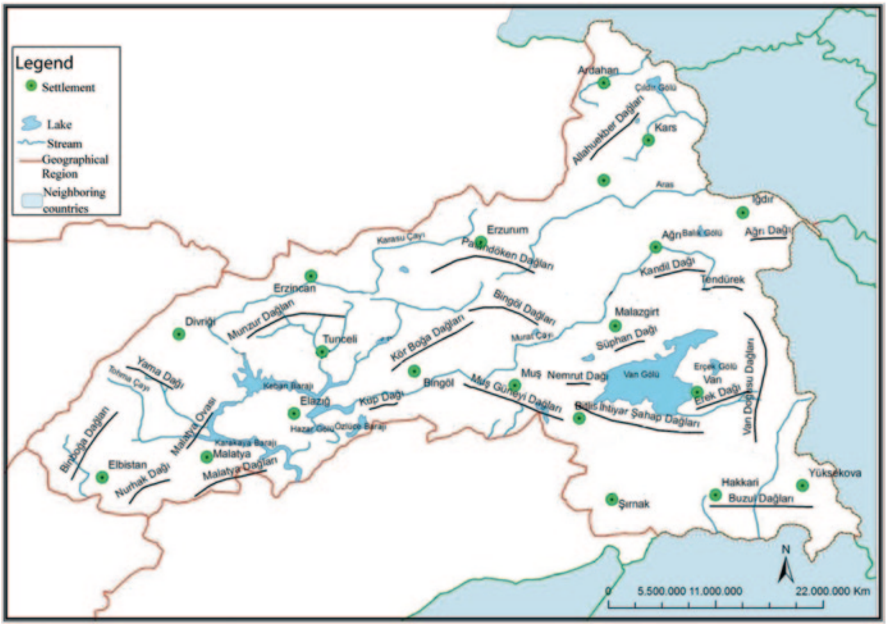

Fig. 11.4 Map of the mountains in the East Anatolia

Fig. 11.5 Agri Mountain in the region of East Anatolia

11.4.3 Plant Dynamics

Natural vegetation is structured by altitude and climate. The mean altitude in Eastern Anatolia is over 1600–1800 m. The climax community of the area is *Pinus sylvestris* L., but it shows a discontinuous distribution. Human activities cause regressive development at *P. sylvestris* L. forests and turn them into damp grasslands outside of agricultural areas.

Glacial movements at geological era contributed the biodiversity in Anatolia. Flora and fauna of Anatolia are influenced from the migration during glacial and interglacial eras. Many species sheltered at Anatolia and during the interglacial era draw back leaving some relict forms behind.

At the East Anatolian plateau, which can be named as the roof of Anatolia with high water table and alluvial and hydromorphic soils over 1600 m, damp grasslands

Fig. 11.6 A view of high mountain steppe from Kisir Mountain

with rich biodiversity develop. These areas are dominated by mesophytic species of almost 100 % cover. Vegetative development starts with melting of snow cover and increasing of temperature at the end of April, and at the end of June and beginning of July flowering and then ripening of seeds occur (Atalay 2006).

Fallowing areas after cereal farming around alluvial-hydromorphic grasslands are covered by *Papaver orientale* L., *Gladiolus atroviolaceus* Boiss., *Onobrychis stenostachya* Freyn, *Vicia cracca* L., *Dianthus calocephalus* Boiss., *Senecio vernalis* Waldst. & Kit., *Anthemis cretica* L., etc.

Due to the influence of continental climate, vegetation period continues till the end of September. The major species of alluvial-hydromorphic grasslands are as follows: *Anthemis cretica* L., *Bromus japanicus* Thunb., *Cyanus depressus* (M.Bieb.) Soják, *Dianthus calocephalus* Boiss., *Eremopoa persica* (Trin.) Roshev, *Erigeron acris* L., *Filago arvensis* L., *Filipendula vulgaris* Moench, *Gladiolus atroviolaceus Boiss.*, *Lotus corniculatus* L., *Medicago x varia* Martyn, *Onobrychis stenostachya* Freyn, *Papaver orientale* L., *Papaver rhoeas* L., *Phleum montanum* K.Koch, *Rumex acetosa* L., *Rumex alpines* L., *Senecio vernalis* Waldst. & Kit., *Sanguisorba minor* L., *Salvia verticillata* L., *Trifolium repens* L., *Trifolium pratense* L., *Vicia cracca* L.

The alluvial-hydromorphic grasslands are dominated by hydrophytes at the places where water table is high. At these areas, naturally growing trees cannot be seen.

These damp grasslands occur either at the sloppy areas with low water table or at partially flat areas, which distinguish them from alluvial-hydromorphic grasslands. Between 1800 and 2700 m, it is the most common vegetation type of the forest and agricultural areas.

The characteristic species of the high mountain steppes of East Anatolia are graminoids (Fig. 11.6) like *Festuca cyllenica* Boiss. & Heldr., *Agrostis stolonifera* L., *Alopecurus aequalis* Sobol., *Bromus pumilio* (Trin.) P. M. Sm., *Dactylis glomerata* L., *Gaudiniopsis macra* (M.Bieb.) Eig, *Phleum pratense* L., *Poa nemoralis* L., *Poa bulbosa* L., *Poa pratensis* L. and *Acanthus dioscoridis* L., *Aster alpinus* L., *Helichrysum plicatum* DC., *Myosotis lithospermifolia* Hornem., *Sibbaldia parviflora* Willd., *Alchemilla caucasica* Buser, *Anthemis cretica* L., *Draba bruniifolia* Steven, *Gentiana verna* L., *Minuartia anatolica* (Boiss.) Woronow.

High mountain steppes are important for livestock production. Vegetative growth increases after the melting of snow cover at the end of April and temperature increases due to continentality. At the beginning of June, transhumance starts and causes early and over grazing, which destroy the vegetation. At the overgrazed

Fig. 11.7 A view of volcanic mother rock from Tendurek Mountain

areas the common species are *Elymus hispidus* (Opiz) Melderis subsp. *hispidus*, *Elymus repens* (L.) Gould, *Alopecurus pratensis* L., *Artemisia* sp., *Alchemilla caucasica* Buser, *Bromus tomentellus* Boiss., *Bromus erectus* Huds., *Cyanus depressus* (M.Bieb.) Soják, *Galium verum* L., *Lotus corniculatus* L., *Medicago x varia* Martyn, *Onobrychis cornuta* (L.) Desv., *Ranunculus millefolius* Sol. subsp. *millefolius*, *Salvia verticillata* L., *Taraxacum officinale* F.H. Wigg., *Trifolium hybridum* L., *Thymus fallax* Fisch. & C.A. Mey., *Veronica orientalis* Mill., *Vicia sativa* L.

11.4.4 Vegetation

The syntaxa of high mountains of East Anatolia belong to the class Astragalo microcephali-Brometea tomentelli. High mountain steppes of East Anatolia connected to the order Festuco oreophilae-Veronicetalia orientalis (Hamzaoglu 2006). This order extends from western side of Anatolian diagonal to Black Sea Mountains at north and to Taurus Mountains at south between 1500 and 3200 m. Hemicryptophytes and chamaephytes reflect the physiognomy. The mother rock on which the order spreads is generally volcanic but also marly and calcareous (Fig. 11.7).

The diagnostic species of the order are *Astragalus lagopoides* Lam., *Astragalus onobrychis* L., *Securigera orientalis* (Mill.) Lassen subsp. *orientalis*, *Festuca brunnescens* (Tzvelev) Galushko, *Medicago papillosa* Boiss., *Onobrychis transcaucasica* Grossh., *Rosa spinosissima* L., S*cutellaria orientalis L.* subsp. *orientalis*, *Thymus transcaucasicus* Ronniger, Veronica *orientalis* Mill. subsp. *orientalis*, *Acantholimon caryophyllaceum* Boiss., *Alyssum pateri* Nyár subsp. *prostratum* (Nyár) T.R. Dudley, *Pulsatilla violacea* Rupr. subsp. *armena* (Boiss.) Luferov, *Artemisia spicigera* K.Koch, *Asperula prostrata* (Adams) K.Koch, *Astragalus cinereus* Willd., *Centaurea rhizantha* C.A.Mey., *Coluteocarpus vesicaria* (L.) Holmboe subsp. *vesicaria*, *Cephalaria sparsipilosa* V.A. Matthews, *Daphne oleoides* Schreb subsp. *kurdica* (Bornm.) Bornm., *Erysimum leptocarpum* J.Gay, *Festuca oreophila* Markgr.-Dann., *Gypsophila bitlisensis* Barkoudah, *Helichrysum arenarium* (L.) Moench. subsp. *rubicundum* (K.Koch) P.H.Davis & Kupicha, *Malabaila dasyantha* (K.Koch) Grossh., *Pimpinella peucedanifolia* Fisch., *Silene montbretiana* Boiss., *Thymus pubescens* Boiss. & Kotschy ex Celak.

Between Gumushane and Bayburt around Coruh and Kelkit at 1500–2200 m at the transition zone between Irano Turanian and Euro Siberian phytogeographical regions, the alliance Tanaceto aucherani–Thymion pubescentis (Hamzaoglu 2006) individualizes. Although the distribution area is not clear, this alliance spreads from Anatolian diagonal from West to Northeast Black Sea Mountains at north and to Otlukbeli, Kop and Gavur mountains at south. The diagnostic species of the alliance are *Achillea schischkinii* Sosn., *Astragalus lagopodioides* Vahl, *Centaurea carduiformis* DC. subsp. *orientalis* Wagenitz., *Isatis candolleana* Boiss., *Tanacetum aucherianum* (DC) Sch. Bip., *Thymus pubescens* Boiss. & Kotschy ex Celak, *Eremogone armeniaca* (Boiss.) Holub, *Erysimum pycnophyllum* J.Gay, *Onobrychis hajastana* Grossh., *Salvia rosifolia* Sm., *Turanecio lorentii* (Hochst.) Hamzaoglu.

The alliance Astragalo aurei-Festucion caucasicae Hamzaoglu 2006 occupies Gavur and Palandoken Mountains around Erzurum, Van, Suphan, and Nemrut Mountains between 2400 and 3200 m at subalpine zone. The alliance spreads on the soils derived from the basalt and andesite mother rock of volcanic origin. The dominant and common species are *Festuca woronowi* Hock. subsp. *caucasia* (St. Yves) Markgr.-Dannenb. and *Astragalus aureus* Willd. The chamaephytes and the hemicryptophytes dominate the physiognomy. The diagnostic species are *Astragalus aureus* Willd., *Cephalaria procera* Fisch. & Avé-Lall., *Festuca woronowii* Hack. subsp. *caucasica* (St. Yves) Markgr.-Dannenb, *Nepeta transcaucasica* Grossh., *Silene arguta* Fenzl, *Vicia alpestris* Steven subsp. *alpestris*, *Erigeron caucasicus* Steven subsp. *venustus* (Botsch.) Grierson, *Poa longifolia* Trin., *Senecio pseudo-orientalis* Schischk.

11.5 The Influence of Global Warming and Climate Change on High Mountain Ecosystems of Central and East Anatolia

Increase in the use of fossil fuels due to the industrial revolution and other greenhouse gasses from anthropogenic sources, cause to change in climate types, to increase in sea level, and to melt of glaciers, which are global environmental problems and lead to threaten the global life.

Global warming have some impacts on alpine habitats like duration of snow cover and its depth decrease (Valt and Cianfarra 2010), rapid glacier retreat reduce (Paul et al. 2004) that change the distribution, phenology and physiology of several plants (Grabherr et al. 1994; Sandvik et al. 2004; Klanderud and Totland 2005; Gottfried et al. 2012).

Consequently, the global warming influences alpine biomes as the others. Also, anthropogenic activities like increasing recreational activities, overgrazing, mining, power sector, etc., seriously threat the alpine biomes locally or regionally (Beniston et al. 1997).

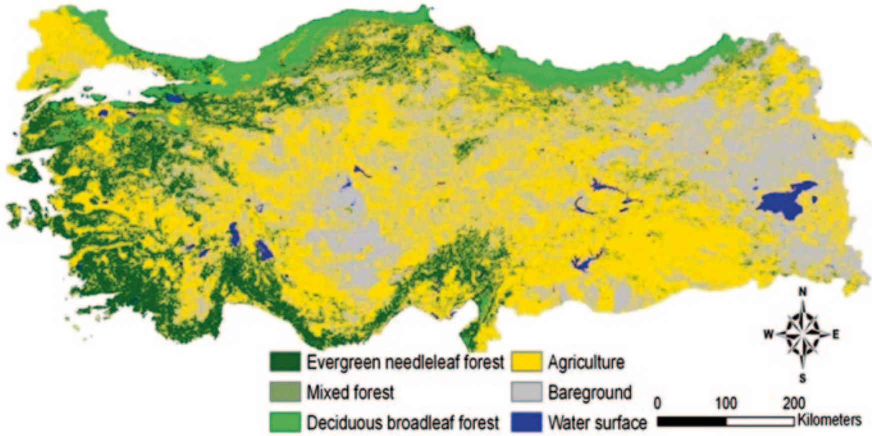

Fig. 11.8 Land cover classification map of Turkey using the MODIS images. (Gulbeyaz 2007; Onder et al. 2009)

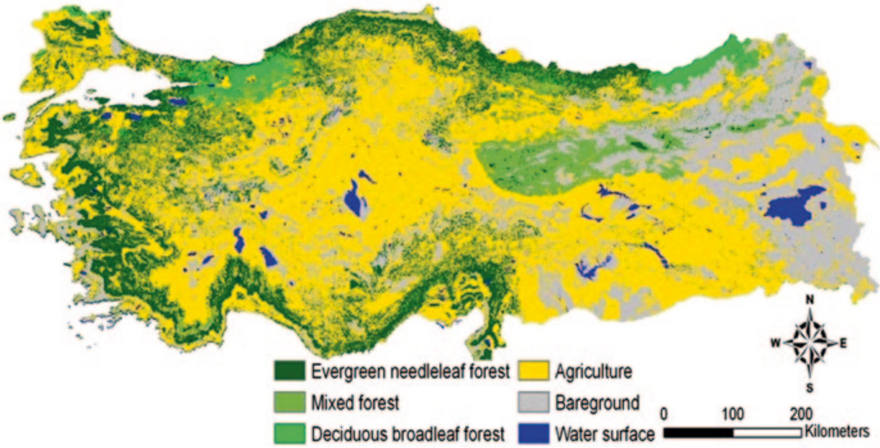

Fig. 11.9 Predicted land cover distribution as a result of future aridity index. (Onder et al. 2009)

Due to its localization in temperate zone, global warming and climate change will influence Turkey most. There is a 70-year model of Turkey about the influence of climate change (Onder et al. 2009; Figs. 11.8 and 11.9). According to this model, precipitation will be 29.6 % lower than today at Mediterranean coast, Central parts, and Firat basin. On the contrary, there will be a 22 % increase in Black Sea coast. This model predicts 2.8–5.5 °C increase in temperature over the country. The increase in temperature triggers the evaporation and raise it by 17.8 % in Mediterranean coast, 18.4 % at Black Sea coast and 22.2 % over the country (Onder et al. 2009; Turkes 2007)

Most of the carbon in the world is accumulated in frozen soils of alpine zone and peatlands. The release of carbon into atmosphere accelerates the warming process. Especially warming triggers the disappearance of permanent snow cover. So, ice cap of volcanic mountains in Central and East Anatolian regions like Agri, Suphan, and Erciyes Mountains are expected to be disappeared.

When the today's vegetation and the expected vegetation of future are compared, it is thought that the evergreen coniferous forests will take the place of deciduous broad-leaved forests. Mixed forests can be spread in middle parts of East Anatolia and Northwest parts of the country (Onder et al. 2009; Sano et al. 2007).

Drought risk is expected to increase in central and southern parts due to increase in temperature, which leads to increase in evapotranspiration and decrease in precipitation. The deficiency of current water sources to meet the demands results in "water stress" locally and naturally. Influences of drought on natural ecosystems have also some sociocultural effects.

Almost 13 million ha of forests was destroyed per year, but nowadays this value is decreased to 7 million ha by reforestation and conservation efforts (FAO 2000). Deforestation is responsible for 20% of the green house gasses emissions, which lead to global warming and so threaten the alpine zone.

There is a desert zone at the south of Turkey. In the next 50 years, it is expected that this zone will extend towards north and increase the temperature especially in Central and Southeast Anatolia, which leads to aridity and desertification. The geographical position, climate, topography, and soil properties of Turkey increase the vulnerability of desertification and drought. There are some important indicators of such situations. In fact, global warming, urbanization, and anthropogenic pressures on natural ecosystems cause extinction of 13 species in last 20 years. And the worst will be expected in next decades.

The expected climate change in the next 50–100 years will influence the biodiversity, ecological processes, natural resource managements, and also the sectors relied on these sources significantly. It is very important for public institutions and universities to deal with the climate change that can lead severe results on ecology, economy, and social life (Aksay et al. 2005; Ketenoglu and Kurt 2012).

For the sustainable use of ecosystems during the climate change, scientific, technological, and sociological capacity should be strengthen. Long-time-monitoring infrastructure should be generated, early warning systems should be built, and risk management should be guaranteed.

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Chapter 12
Climate Change Impact on High-Altitude Ecosystems and Their Impact on Human Communities

Case Study: San Bernardino Mountains and Urban Communities Interface: Historical, Contemporary, and Future

Paul W. Bierman-Lytle

12.1 Introduction

Global Overview of High-Altitude Ecosystems:

Half of the Human Population Depends on Mountains Defined by elevation above sea level (minimum between 300 and 1000 m, depending on latitude), steepness of slope (at least 2° over 25 km, on a 30-arc-second grid), and excluding large plateaus, mountains occupy about one fifth of Earth's terrestrial surface. Twenty percent (1.2 billion) of the world's human population live in mountains or at their edges, and half of the humankind depends in one way or the other on mountain resources (largely water).

Mountains are Characterized by High Biodiversity Because of the compression of climatic life zones with altitude and small-scale habitat diversity caused by different topo-climates, mountain regions are commonly more diverse than lowlands and are thus of prime conservation value. They support about one quarter of terrestrial biodiversity, with nearly half of the world's biodiversity hot spots concentrated in mountains. Geographically fragmented mountains support a high ethno-cultural diversity. For many societies, mountains have spiritual significance, and scenic landscapes and clean air make mountains target regions for recreation and tourism. Thirty-two percent of protected areas are in mountains (9345 mountain protected areas covering about 1.7 million km^2).

Mountain Ecosystems are Exceptionally Fragile Mountains are subject to both natural and anthropogenic drivers of change. These range from volcanic and seismic events and flooding to global climate change and the loss of vegetation and soils because of

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inappropriate agricultural and forestry practices and extractive industries. Mountain biota are adapted to relatively narrow ranges of temperature (and hence altitude) and precipitation. Because of the sloping terrain and the relatively thin soils, the recovery of mountain ecosystems from disturbances is typically slow or does not occur.

Human Well-Being Depends on Mountain Resources These ecosystems are particularly important for the provision of clean water, and their ecological integrity is key to the safety of settlements and transport routes. They harbor rich biodiversity and contribute substantially to global plant and animal production. All these services depend on slope stability and erosion control provided by a healthy vegetative cover. As "water towers," mountains supply water to nearly half of the human population, including some regions far from mountains, and mountain agriculture provides subsistence for about half a billion people. Key mountain resources and services include water for hydroelectricity, flood control, mineral resources, timber, and medicinal plants. Mountain populations have evolved a high diversity of cultures, including languages, and traditional agricultural knowledge commonly promotes sustainable production systems. In many mountain areas, tourism is a special form of highland–lowland interaction and forms the backbone of regional as well as national economies.

Defining Mountains by Topography Only The United Nations Environment Program–World Conservation Monitoring Center has adopted criteria based on altitude and slope in combination to represent the world's mountain environments.[1] Topographical data from the GTOPO30 global digital elevation model (USGS EROS Data Centre 1996) were used to generate slope and local elevation range on a 30-arc-second (about 1 km) grid of the world. These parameters were combined with elevation to arrive at empirically derived definitions of six elevation classes. To reduce projection distortion in the original data set, analysis was based on continental subsets in equidistant conic projection. The global mountain area thus defined is almost 40 million km^2, or 27 % of Earth's surface. Assuming a lower mountain boundary of 1000 m at the equator and a linear reduction of this boundary to 300 m at 67°N and 55°S reduced the total "mountain" land area by 5.4 million km^2 or 3.7 % of the global land.[2]

Class 1, elevation > 4500 m
Class 2, elevation 3500–4500 m
Class 3, elevation 2500–3500 m (San Bernardino Mountain range)
Class 4, elevation 1500–2500 m and slope ≥ 2 (San Bernardino Mountain range)
Class 5, elevation 1000–1500 m and slope ≥ 5 or local elevation range (7 km radius) > 300 m
Class 6, elevation 300–1000 m and local elevation range (7 km radius) > 300 m outside 23°N to 19°S
Class 7, isolated inner basins and plateaus less than 25 km^2 in extent that are surrounded by mountains but do not themselves meet criteria 1–6 (this seventh class was introduced in the 2002 revision of the original 2000 system)[3]

[1] Kapos et al. 2009.
[2] Millennium Ecosystem Assessment, World Resources Institute (2005b, p. 684).
[3] Millennium Ecosystem Assessment, World Resources Institute (2005b, p. 684).

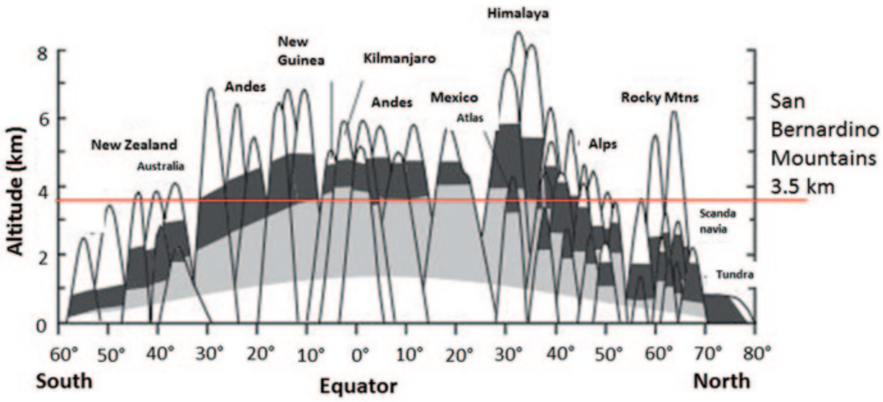

Fig. 12.1 Classic Humboldt Profile of the latitudinal position of altitude belts in mountains across the globe and compression of thermal zones on mountains, altitude for latitude. *Grey* is montane; *black* is alpine; *white* is the nival belt (© Millennium Ecosystem Assessment, World Resources Institute 2005a)

In this global assessment, three belts were distinguished for mountain regions where precipitation regimes allow forest growth. In treeless arid or semiarid regions, analogues to these belts can be defined (see Fig. 12.1).

- *The montane belt* extends from the lower mountain limit to the upper thermal limit of forest (irrespective of whether forest is present or not). This limit has a mean growing season temperature of 6.7 + 0.8 °C globally, but is closer to 5.5 °C near the equator and to 7.5 °C near temperate latitudes. Between 40°N and 30°S, this belt covers a range of 2000–3000 m of elevation.
- *The alpine belt* is the treeless region between the natural climatic forest limit and the snow line. The term "alpine" has many meanings, but here it refers strictly to a temperature-driven treeless high-altitude life zone that occurs worldwide and not solely in the European Alps (the term "alp" is of pre-Indo Germanic origin). Some synonyms such as "andean" and "afro-alpine" are in common scientific use. Land cover is dominated by grassland or low-stature shrubland. Outside subpolar regions (< 60°N, < 50°S), the alpine belt extends over an elevation range of 800–1200 m, with its lower boundary varying from about 500 to 4000 m above sea level, depending on latitude.
- *The nival belt* is the terrain above the snow line, which is defined as the lowest elevation where snow is commonly present all year round (though not necessarily with full cover). While the lower part of the nival belt is still rich in living organisms, usually very little plant and animal life is found beyond 1000–2000 m above the tree line, although animals and flowering plants can be found up to around 6000 m in some parts of the world (Figs. 12.2, 12.3, and 12.4).[4]

[4] Millennium Ecosystem Assessment, World Resources Institute (2005b, pp. 684–685).

Fig. 12.2 San Bernardino Mountains. (©Peakbagger 2004)

Fig. 12.3 San Bernardino Mountain range. (©Peakbagger 2004)

12.2 Origins of the San Bernardino Mountain Range Ecosystem

Tectonic plate movement along the San Andreas Fault,[5] commonly called the Transverse Range, formed the San Bernardino and neighboring mountain ranges approximately 11 million years ago. The mountains are still actively rising, a few millimeter

[5] The San Andreas Fault is a continental transform fault that extends roughly 810 miles (1300 km) through California in the USA. It forms the tectonic boundary between the Pacific Plate and the North American Plate, and its motion is right-lateral strike slip (horizontal). The fault divides into three segments, each with different characteristics, and a different degree of earthquake risk. Although the most significant (Southern) segment only dates back about 5 million years, the oldest sections were formed by the subduction of a spreading ridge 30 million years ago.

Fig. 12.4 California in the USA. (©Magellan Geographics, Santa Barbara, California, 1992)

per year. The fault runs along the southern base of the San Bernardino Mountains, crosses through the Cajon Pass and continues the Northwest along the northern base of the San Gabriel Mountains. Many local rivers originate in the range, which receives significantly more precipitation than the surrounding desert. The range's unique and varying environment allows it to maintain some of the greatest biodiversity in the state (Fig. 12.5).

The San Bernardinos, 34°08′N 116°53′W, run for approximately 60 miles (97 km) from Cajon Pass in the Northwest—which separates them from the San Gabriel Mountains—to San Gorgonio Pass, across which lie the San Jacinto Mountains, in the Southeast. The Morongo Valley in the Southeast divides the range from the Little San Bernardino Mountains.[6] Encompassing roughly 2100 miles^2 (5439 km^2), the mountains lie mostly in San Bernardino County, with a small southern portion reaching into Riverside County. The range divides three major physiographic regions: the highly urbanized Inland Empire to the Southwest, the Coachella Valley in the Southeast, and the Mojave Desert to the North. Most of the range lies within the boundaries of the San Bernardino National Forest.

The San Bernardino Mountains are the highest range south of the Sierra Nevadas, and are also unique in being one of the few transverse ranges in the USA. This huge and rugged country is filled with history, romantic legends, and magnificent scenery, which are many reasons human communities have originated and settled in and around the high-altitude range. Proclaimed a "Forest Reserve" on February 25, 1893, these mountains were redesignated as the San Bernardino National Forest by presidential proclamation in 1925. This vast area is much larger than the State of Rhode Island at 1058 square miles (2740 km^2). Within the boundary of the National Forest are 812,633 acres (328,861 ha), of which 198,042 acres (80,145 ha) are state and private lands. The San Gorgonio Wilderness runs along the southern spine of this mountain range, and consists of 33,898 extremely rugged acres (13,718 ha). The highest

[6] http://www.bigbearhistory.org/sbdomtns.htm.

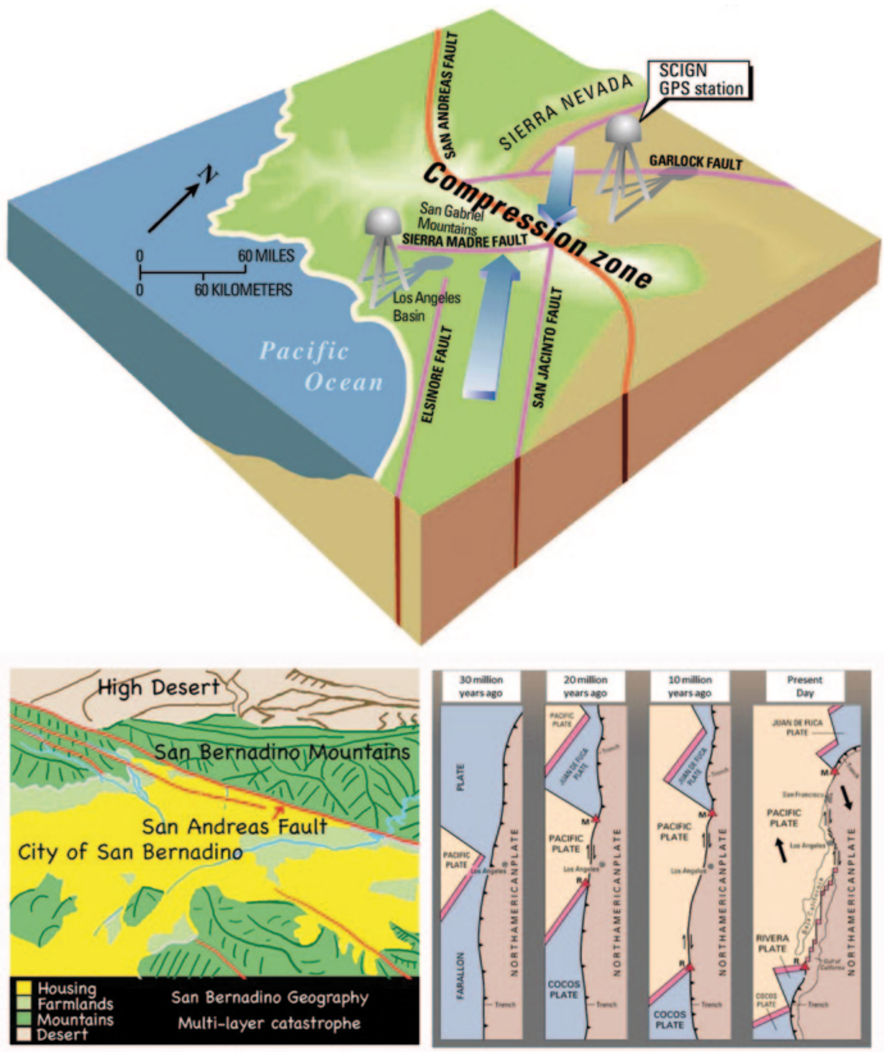

Fig. 12.5 Tectonic plate forming the San Bernardino Mountains—11,000,000 years ago (U.S. Geological Survey 2006)

mountain in Southern California, Mt. San Gorgonio—nicknamed Old Greyback—at 11,502 ft. (3500 m), stands well above several others reaching over 10,000 ft. (3050 m)—Dobbs Peak, Jepson Peak, Charlton Peak, and San Bernardino Peak.

San Bernardino Mountain Ecosystem DNA What is this mountain ecosystem made of and what is its quantitative and qualitative natural capital value?

An early version of the range rose in the Miocene, between 11 and 5 million years ago, but has largely eroded. The range was shaped into its present form during the Pleistocene epoch beginning approximately 2 million years ago, with regional uplift continuing to the present. The rocks that make up the mountains are much more ancient than the mountains themselves—ranging from 18 million to 1.7 billion years old.[7]

These mountains are shaped by several primary tectonic or fault blocks—the Big Bear block, which forms the large montane plateau that characterizes the northern portions of the range; and the more complex and fractured San Gorgonio, Wilson Creek, and Yucaipa Ridge blocks, which form the rugged and heavily dissected southern parts of the mountains.[8] Because of their large, steep rise above the surrounding terrain, the San Bernardinos have been subject to great amounts of erosion that have carved out numerous river gorges. Rocks and sediment from the mountains are deposited on the surrounding valley floors as massive alluvial fans.[9] Regional alluvial deposits can reach the depths of 1000 ft. (300 m) or more, and their permeable soils constitute several major groundwater basins.[10][11]

The modern landscape of the San Bernardino Mountains is a product of erosional dissection by streams and rivers that are gradually stripping away rock products and carrying them downstream to alluvial basins at the base of the range. The next few million years of earth history will witness a competition between erosional agents that will tend to reduce the elevation of the San Bernardino Mountains and tectonic agents that may continue to increase their elevation.[12]

The San Bernardino Mountains, along with the nearby San Gabriel and San Jacinto ranges, are considered a sky island—a high mountain region whose plants and animals vary dramatically from those in the surrounding semiarid lands. The San Bernardinos in particular comprise the largest forested region in Southern California, and support some 1600 species of plants. Foothill regions are primarily composed of chaparral and evergreen oak woodland communities, with a transition to forests of deciduous oak, yellow pine, Jeffrey pine, incense cedar, and several fir species at elevations above 5000 ft. (1500 m). Deeper within the mountains, perennial streams fed by springs and lakes nourish stands of alders, willows, and cottonwoods.[13]

Roughly 440 species of wildlife inhabit the mountains,[14] including 71 endangered animal species such as the San Bernardino flying squirrel, California spotted owl, mountain yellow-legged frog, southern rubber boa, and Andrew's marbled butterfly, and 85 flora species.[15] The mountains once had an abundant population of California grizzly bear, but hunting eliminated their populations by 1906.[16]Black bears roam

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[7] U.S. Geological Survey (2006).

[8] Spotila et al. (1998–2006).

[9] Mattic and Morton (2000).

[10] Eckis (1928).

[11] Gandhok et al. (1999).

[12] http://geomaps.wr.usgs.gov/archive/scamp/html/scg_trans_sbmt.html, USGS, Southern California Geological Survey, Bailey and Jahns (1954); Dibblee (1982b); Matti and Morton (1993); Matti et al. (1992a, 1992b); Miller (1946); Sadler(1981, 1982); Spotila et al. (1999).

[13] U.S. Forest Service (2009a).

[14] U.S. Forest Service (2009a)

[15] "Endangered species". *Mountains Group—San Gorgonio Chapter*. Sierra Club.

[16] "Black Bear Management Plan." California Department of Fish and Game (1998–2007).

Fig. 12.6 American bald eagle. (© U.S. Department of Agriculture (USDA), 2009)

Fig. 12.7 Coral snake. (© U.S. Department of Agriculture, 2009)

Fig. 12.8 Sub-alpine forest. (© USDA, 2009)

the highlands today, but they are not native to the region: they were imported from the Sierra Nevada by the California Department of Fish and Game in the 1930s, in part to attract tourists to the mountains (Figs. 12.6, 12.7, 12.8, and 12.9).[17]

[17] "Black Bear Management Plan". California Department of Fish and Game (1998–2007).

Fig. 12.9 Black bear. (non-native species) (© USDA, 2009)

12.3 Historical Relationships Between Human Communities and this High-Altitude Ecosystem

12.3.1 Native Americans: The First People

Archaeological discoveries in the San Bernardino Valley suggest that humans have populated the region for at least 10,000–12,000 years.[18] Several Native American groups held the lands surrounding the San Bernardinos. Most of these tribes did not have permanent settlements in the mountains, with the possible exception of a few groups of Serrano (Figs. 12.10, and 12.11).[19]

The Spanish explorers who first came upon Big Bear Valley named the Native Americans who lived here the "Serranos," which means mountaineers. The Serranos are thought to be Shoshonean by descent, and they probably gradually migrated to the San Bernardino Mountains from the Wind River country of Wyoming some 3000 years ago. Once in Southern California, the Serranos were not extensive travelers, and their range was within an area marked by the Mojave Desert, San Bernardino Valley, and Mt. San Jacinto. Their summer encampments were spent mostly in the San Bernardino Mountains. Their dwellings were made of poles and tulle grass or brush and had a smoke hole at the top. A center fire pit was only for heating, as all cooking was done outside. The floor was covered with tulle mats, and these and animal skins were used for bedding. Acorn mush was a basic food. It was pounded from nuts gathered in the fall from black oaks near Oak Glen. Pinion nuts were also a favorite, with Big Bear Valley a main source. Other foods were mesquite beans, berries, chia seeds, roots, tubers, bulbs, and sage. Rodents, birds, insects, reptiles, fish, rabbits, and deer were also part of their diet.

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[18] "San Bernardino County History." County of San Bernardino (2008).

[19] Robinson and Harris (2006).

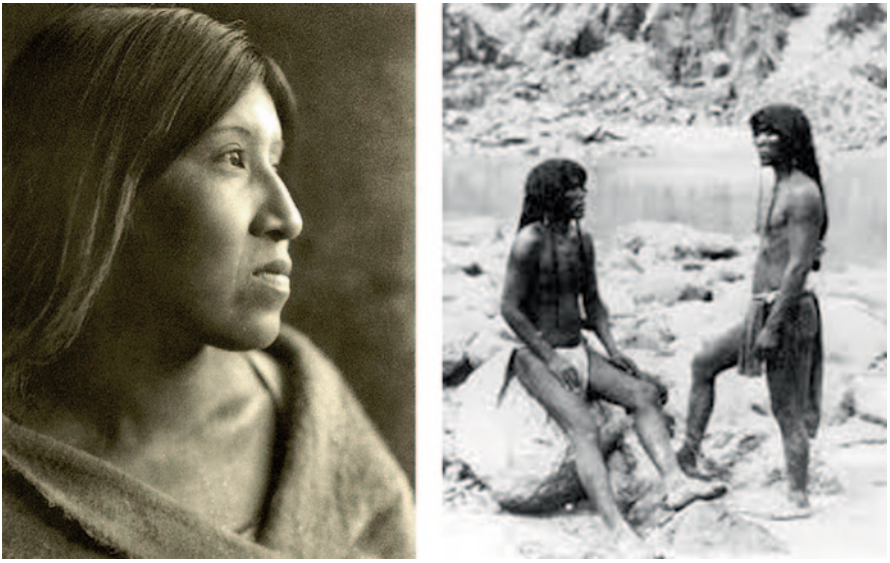

Fig. 12.10 Desert Cahuilla woman and native Serranos. (© Edward S. Curtis, 1926)

Fig. 12.11 Fibrous threads on leaf segments (*Washingtonia filifera*). (© U.S. Forest Service, 2012)

The Serrano women were accomplished pottery makers; their Tizon ware was thin, delicate, and beautifully decorated with free hand patterns in a wide variety of colors. They also made excellent baskets from natural fibers that were decorated with eagle, rattlesnake, sun, moon, and many other designs. The Serranos held the grizzly bear in deep reverence, and thought of these huge animals as great grandfathers. Bear meat was never eaten, nor was bear fur ever worn. Ravaged by smallpox sometime after 1774, the Serrano population had declined to about 100 when the

Fig. 12.12 The mountains are named for the San Bernardino Valley, in turn named by the Spanish in 1810. (© Jeremy Miles, 2007)

1910 census was taken.[20] They would have traveled into the mountains in the summer to hunt deer and rabbits, gather acorns, berries, and nuts, and seek refuge from the desert heat.[21] They established well-traveled trade routes, some of which were later used by Europeans to explore and settle the region. Much of the evidence of their camps and settlements is now gone due to development. The Serrano lived in pit houses and constructed brush shelters during the milder times of the year. They moved from the lower elevations where they resided in the winter months to the higher elevations in the springtime to gather plants. It is still possible to find smooth grinding stones (manos or metates) and mortar holes in rock, where acorns and seeds were prepared for food. Occasionally visitors find pieces of pottery or arrowheads.

12.3.2 Pioneers (European/Americans)

Spanish explorers first came upon the San Bernardino Mountains in the late 1700s, naming the eponymous San Bernardino Valley at its base. European settlement of the region progressed slowly until 1860, when the mountains became the focus of the largest gold rush ever to occur in Southern California. Waves of settlers brought in by the gold rush populated the lowlands around the San Bernardinos, and began to tap the mountains' rich timber and water resources on a large scale by the late nineteenth century.

During the 1600s and 1700s, various Spanish explorers passed through coastal Southern California and claimed the area for Spain. In 1769, the Spanish government began an effort to bring what they called Alta California under their control and introduce Christianity to native peoples through the construction of missions (Figs. 12.12, and 12.13).[22]

Beginning in 1851, Mormon colonists began emigrating to the San Bernardino Valley. The Mormons bought and subsequently split up Rancho San Bernardino, and greatly improved the area's agricultural production by bringing in thousands of head of livestock and overhauling the local irrigation network.[23]

[20] Big Bear Valley Historical Society (2013).

[21] U.S. Forest Service (2009b).

[22] Clugston, Steve. "The Real El Camino: California Missions in Another Light". University of California Riverside.

[23] Guinn (1902).

Fig. 12.13 The Mill Creek valley was the first area of the mountains to be logged. (© J. Cook Fisher, 2007)

12.3.3 Human Uses of the High-Altitude Ecosystem

For thousands of years, the Native Americans, one can say, lived "softly" on the ecosystem; indeed, their "footprint" of settlement and use of the mountain resources have all but vanished today. They took what was needed for their survival, food, shelter, materials for clothing, vegetation for making baskets, earth for pottery, feathers for decoration, water for nourishment. They respected and revered certain wildlife, such as the bear and eagle, and would not hunt them. Ironically, today, both are endangered due to European explorers and hunters. So in contrast to the original human communities, the next group of humans entering the ecosystem viewed the natural resources differently. Every aspect of the ecosystem was seen as a resource to make money. In other words, the ecosystem was a bank or reserve for human commerce. And since the ecosystem was seemingly "abundant," no regard for preservation, restoration, or management was included in the "commercial" ventures. Not until the US government instated the US Department of Agriculture (USDA) Division of Forestry in the early 1900s were portions of the ecosystem protected from human exploitation. The human "commerce" derived from the high-altitude ecosystem included:

- *Agriculture*
  In 1880, Frank Elwood Brown designed the first dam in the Big Bear Valley, forming Big Bear Lake—the world's largest artificial reservoir at the time—to supply water to citrus farms around San Bernardino
- *Fox farming*
  The raising of foxes for their magnificent furs dates from the 1890s. The high altitude and dry air eliminated many internal and external pests, while the cool summer nights, seasonal changes, and cold winters were ideal for the fur industry. The pen-raised silver foxes were flighty, nervous, and unpredictable, and required diligent care and feeding. Superior breeding pairs would bring US$ 2000–3000 and fine pelts would command as much as US$ 1100. The demise of the fox fur industry was the result of several factors: the increased cost of food, a 20 % luxury tax, and Russia and other lend-lease countries dumped shiploads of fur on the world market.[24]

[24] http://www.bigbearhistory.org/foxfarm.htm.

- *Mountain Cattle Ranches*
  As early as 1857, cattle and sheep were grazing in the San Bernardino Mountains in large numbers. The peak of mountain cattle ranching lasted for about 60 years, from the 1880s until the 1940s.
- *Logging and sawmills*
  Around 1845, lumber was needed for sheds and wine kegs for the Los Angeles Vineyard. This was followed by the Mormons who began their settlement of San Bernardino in 1851. One of their vital needs was for lumber. By 1854, six sawmills were producing lumber and shingles. By 1892, one company alone had logged 8000 acres.
- *Mining*
  The Holcomb Valley gold rush of 1860 brought hundreds of miners into the area. Digging into the "ecosystem" required huge railroad steam shovels that could dig 1000 yards of gravel a day. The long windrows made by this shovel are still visible today. With this exception, no structures remain at any of these historic mines, and only caved in tunnels, collapsing shafts, and piles of colorful tailings are evidence that they once existed.[25]
- *Gold rush*
  Beginning in 1860, the California gold rush drew hundreds of settlers to the high-altitude mountains. Soon the little communities of Belleville, Union Flat and Clapboard Town had been built. It is estimated that between 1500 and 2000 people were in Holcomb Valley during the peak of the boom in the 1860s.[26]
- *Dams*
  With the arrival of the Southern Pacific in Southern California in 1876, the area boomed as people flocked to the new land. When Frank E. Brown and E. G. Judson established the town site of Redlands in 1879, they looked toward the mountains for additional water for their new agricultural community. The first dam was built in1884. It was 60 ft. high (18.3 m) and 300 ft. (91.5 m) wide and contained 3304 cubic yards (2526 m^3) of rock work and 1600 barrels (191,000 L) of cement. The total cost for labor and materials was US$ 68,000. At that time, the Bear Valley Dam created the largest man-made lake in the world, and was also considered the eighth wonder of the world because it held! In 1911, J. S. Eastwood built the present multiple-arch dam, which tripled the capacity of the lake to 73,000 acre-feet (af). This dam was 20 ft. (6 m) higher and cost US$ 138,000 to construct. This 1911 dam was reinforced in 1988 to comply with increased earthquake safety standards at a cost of nearly US$ 13,000,000![27]
- *Recreation resorts*
  Recreational development of the mountain range began in the early 1900s, when mountain resorts were built around these new irrigation reservoirs created by dams. Since then, the mountains have been extensively engineered for transportation and water supply purposes. Four major state highways and the

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[25] http://www.bigbearhistory.org/mining.htm.

[26] http://www.bigbearhistory.org/goldrush.htm.

[27] http://www.bigbearhistory.org/dams.htm.

> California Aqueduct traverse the mountains today; these developments have all had significant impacts on area wildlife and plant communities. Most early tourists arrived by stagecoach, though in time the old Mormon logging road through Waterman Canyon was overhauled, allowing for the passage of automobiles.[28]

The development of resorts also proliferated on rivers and high mountain valleys. Snow in the San Bernardinos was seen as an obstacle before the 1920s and practically shut down recreation in the winter. However, more and more Southern Californians braved the dangers of winter travel in the mountains, and the mountain resorts became a sought-after winter destination by the 1930s.[29]Skiing did not become a popular recreational activity in the mountains until a simple sling lift was built at Big Bear in 1938.[30] By 1949, a 3000-ft.-long (910 m) chair lift was built, hugely increasing the amount of skiers the area's resorts could accommodate.

Tourism is the primary economic generator for the area, contributing millions of dollars per year to the county and providing over 2000 full-time and 1000 part-time jobs for approximately 50,000 local residents. The majority of mountain residents commute to the urban cities below each day. The mountain resort towns are host to over 5 million visitors a year.

12.4 Modern Relationships: Mountain Communities, San Bernardino City, and the New Community, Arrowhead Springs

The history of human communities' impact on high-altitude ecosystems is consistent, with the exception of the original Native Americans. It is also one-sided. Humans have, repeatedly and predictably, past and present, taken from the ecosystem, the natural capital,[31] but return little, if anything that contributes to the ecosystem's sustainability. And, typically, humans conduct this behavior at the peril of losing the ecosystem's value: Exploitation of flora and fauna for food, clothing, and daily living amenities (earthenware, baskets, shelter, utensils); extraction of precious metals for adornment, currency, and products; timber for heat, buildings, transportation, furniture, and other human necessities or luxuries; water for drinking, agriculture, and energy; and enjoyment (to the point of overuse) of the "natural" beauty and climate of these high-altitude ecosystems, in the form of resorts and recreation. Each of these "uses" of mountain ecosystem resources results in the establish-

[28] http://www.bigbearhistory.org/dams.htm, pp. 34–35.

[29] http://en.wikipedia.org/wiki/San_Bernardino_Mountains#cite_note-53.

[30] http://en.wikipedia.org/wiki/San_Bernardino_Mountains#cite_note-54.

[31] "Natural capital is the land, air, water, living organisms, and all formations of the Earth's biosphere that provide us with ecosystem goods and services imperative for survival and well-being. Furthermore, it is the basis for all human economic activity." International Institute for Sustainable Development (IISD), Winnipeg, Manitoba, Canada (2010).

ment of permanent human settlements. Humans, above all other living organisms, exhibit a propensity to dominate whatever resources we encounter, including our own species (i.e., Native Americans). Natural and human capital, it appears, is for our unrestricted use, manipulation, enjoyment whenever, wherever, and however we choose. This "DNA" makeup of human populations, most behavioral ecologists conclude, is exactly the reason we humans have evolved as "masters" of all species. Yet, it could also be our demise, or at least, the diminution of our quality of life, though most current societies do not recognize this path or conclusion. The exploitive trends remain the same, and the appreciation or understanding of the values natural capital contribute continues to be a very low priority. One major factor that may encourage humans to begin acknowledging high-altitude ecosystems value is climate change. The impacts on both natural capital and human communities will be real, tangible, and monetizable.

12.5 The "Elephant in the Room": Climate Change and its Impact on High-Altitude Ecosystems and the Resulting Impact on Human Communities

The San Bernardino Mountains, the "sky island" as it is classified, is a perfect case study for climate change impacts on the ecosystem and on the human communities that depend on it. The approach taken in this case study follows the outline below[32]:

Phase 1: identify and quantify the ecosystem service value, or "natural capital."
Phase 2: identify existing human community value that results from ecosystem service value.
Phase 3: identify climate change impacts, positive and negative, on both ecosystem service value and human community value
Phase 4: identify paths forward to reduce negative impacts and/or how human communities must adapt to climate change impacts.

12.5.1 Phase 1: Identify and Quantify the Ecosystem Service Value, or "Natural Capital"

Ecosystem service value, or "natural capital," includes:

- *Food.* This includes the vast range of food products derived from plants, animals, and microbes.
- *Fiber.* Materials included here are wood, jute, cotton, hemp, silk, and wool.
- *Fuel.* Wood, dung, and other biological materials serve as sources of energy.

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[32] Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 9).

- *Genetic resources.* These include the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines*, and *pharmaceuticals*. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources.* Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments.
- *Freshwater.* People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, it could also be considered a supporting service.

12.5.1.1 Regulating Services

These are the benefits obtained from the regulation of ecosystem processes, including:

- *Air quality regulation.* Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- *Climate regulation.* Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation.* The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- *Erosion regulation.* Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment.* Ecosystems can not only be a source of impurities (for instance, in freshwater) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.
- *Disease regulation.* Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Pest regulation.* Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination.* Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Natural hazard regulation.* The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

12.5.1.2 Cultural Services

These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity.* The diversity of ecosystems is one factor influencing the diversity of cultures. For example, high-altitude ecosystems often impact how people respond to their environments; i.e., food, shelter, ornament, agriculture versus nomadic lifestyle, resulting in cultural and heritage roots.
- *Spiritual and religious values.* Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems* (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures. Seasonal patterns in the environment, such as animal and bird migrations, flowering of plants, and uses of plants and minerals for health become knowledge passed down from generation to generation.
- *Educational values.* Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Learning how the world works through one's environment has always advanced primitive communities to more informed civilizations.
- *Inspiration.* Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values.* Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.
- *Social relations.* Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place.* Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values.* Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- *Recreation and ecotourism.* People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

12.5.1.3 Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the timescale and immediacy of their impact on people.)

These services include:

- *Soil formation*. Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- *Photosynthesis*. Photosynthesis produces oxygen necessary for most living organisms.
- *Primary production*. The assimilation or accumulation of energy and nutrients by organisms.
- *Nutrient cycling*. Approximately, 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling*. Water cycles through ecosystems and is essential for living organisms.

Ecosystem services are the benefits people obtain from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling (see Fig. 12.14). The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.[33]

12.5.1.4 San Bernardino High-Altitude Ecosystem Services Value

Estimated ecosystem services value (ESV) = US$ 290 billion covering 637,000 ha (1,574,400 acres)
Values include:

- Mixed forest
- Urban green
- Open water and streams
- Wetlands
- Habitat refugium
- Recreation
- Aesthetic and amenity
- Water regulation and supply
- Climate and atmospheric regulation

No values could be estimated for:

- Food and raw materials
- Soil retention and formation
- Waste assimilation

[33] Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 9).

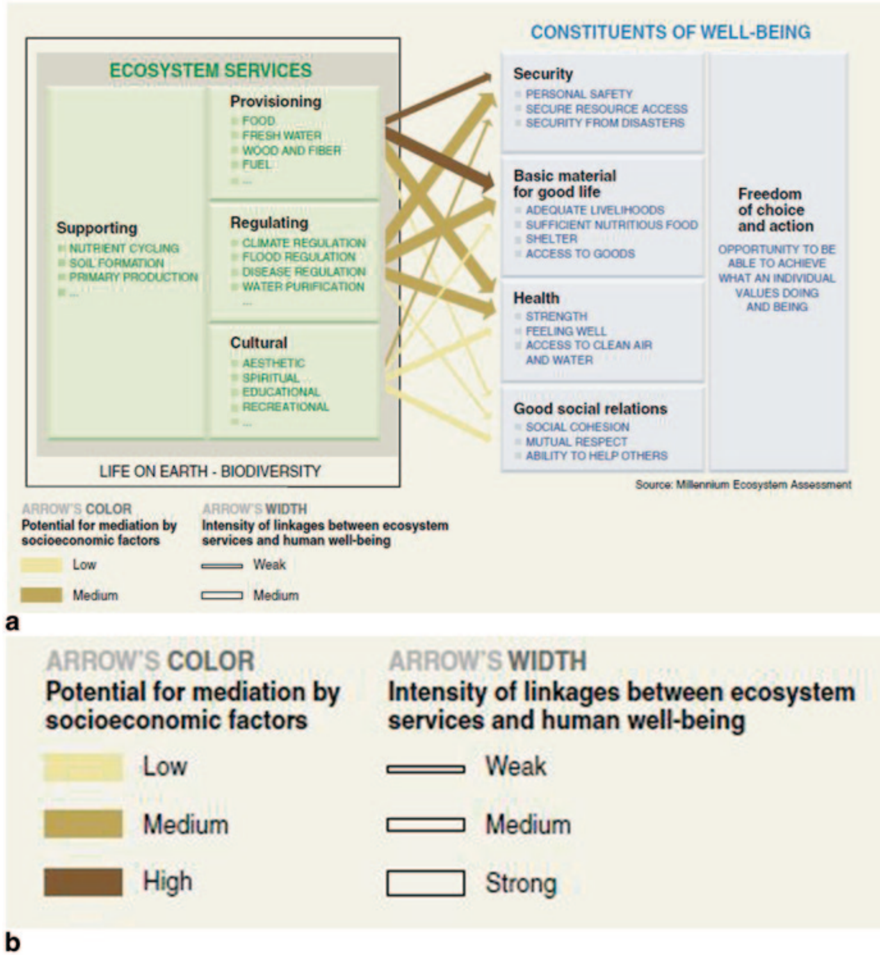

Fig. 12.14 © Millennium Ecosystem Assessment, World Resources Institute (2005a, b)

The ESV was derived from the following methodology developed by Troy and Wilson.[34]

12.5.1.5 Spatially Explicit Ecosystem Value Transfer

Value transfer involves the adaptation of existing valuation information to new policy contexts where valuation data are absent or limited.For ESVs, this involves searching the literature for valuation studies on ecosystem services associated with ecological resource types present at the policy site. Value estimates are then

[34] Troy and Wilson (2006, pp. 435–449).

transferred from the original study site to the policy site. Value transfer has become an increasingly practical way to inform decisions when primary data collection is not feasible due to budget and time constraints, or when expected payoffs to original research are small. As such, the transfer method is now seen as an important tool for environmental policy makers since it can be used to relatively quickly estimate the economic values associated with a particular landscape for less time and expense than a new primary study.

The approach developed by Troy and Wilson forms the foundation of the Natural Assets Information System™, a decision support system framework developed by Spatial Informatics Group, Limited Liability Company (LLC) (http://www.sig-gis.com). The framework, which builds upon the value transfer methodology, is implemented in three case studies and consists of seven core steps: (1) spatial designation of the study extent; (2) establishment of a land covertypology whose classes predict significant differences in the flow and value of ecosystem services; (3) meta-analysis of peer-reviewed valuation literature to link per unit area coefficients to available cover types; (4) mapping land cover and associated ecosystem service flows; (5) calculation of total ESV and breakdown by cover class; (6) tabulation and summary of ESVs by relevant management geographies, and (7) scenario or historic change analysis.

Step 1: Study Area Definition

Study area definition is an essential but often underappreciated first step, since small boundary adjustments can have large impacts on final ESV estimates. While the client's desired target area for study may correspond neatly with administrative or political boundaries those may or may not correspond with relevant biogeophysical boundaries.

Step 2: Typology Development

The development of a land cover typology starts with a preliminary survey of available geographic information system (GIS) data at the site to determine the basic land cover types present. This is followed by a preliminary review of economic studies (see step 3) to determine whether ecosystem service value coefficients have been documented for these cover types in a relatively similar context.

Step 3: Literature Search and Analysis

The collected empirical studies, preferably from a similar context, are read and analyzed to extract valuation coefficients for ecosystem services associated with each cover class in the typology. The information includes the ecosystem service and cover type valued, valuation method, year of study, and per hectare value estimates, among other attributes.

There are three broad categories of valuation studies that exist in the field today:

1. Peer-reviewed journal articles, books and book chapters, proceedings, and technical reports that use conventional environmental economic valuation techniques and are restricted to an analysis of social and economic values. These are the most desirable studies.
2. Non-peer-reviewed publications that include PhD dissertations, technical reports, and proceedings, as well as public raw data.
3. Secondary analysis (e.g., meta-analysis) of peer-reviewed and/or non-peer-reviewed studies that use conventional or nonconventional valuation methods.

Step 4: Mapping

Map creation involves GIS overlay analysis and geo-processing to combine input layers from diverse sources to derive the final land cover map.

Step 5: Total Value Calculation

Once each mapping unit is assigned a cover type, it can then be assigned a value multiplier from the economic literature, allowing ecosystem service values to be summed and cross-tabulated by service and land cover type. The total ecosystem service value flow of a given cover type is then calculated by adding up the individual, non-substitutable ecosystem service values associated with that cover type and multiplying by area as given below.

$$V(\mathrm{ES_i}) = \sum_{k=1}^{n} A(\mathrm{LU_i}) \times V(\mathrm{ES_{ki}})$$

where A(LUi) = area of land use/cover type (i) and V(ESki) = annual value per unit area for ecosystem service type (k) generated by land use/cover type (i).

Step 6: Geographic Summaries

In the fifth step, land cover areas and ESVs are summarized by a geographical aggregation unit. While ESVs can be mapped by the original minimum mapping unit (e.g., a land cover pixel), for large map extents with small minimum mapping units (pixels are frequently 30 m on a side or smaller), patterns may be visually imperceptible and so geographic aggregation is often warranted. Moreover, managers may be interested in visually displaying the value of ecosystem services by some geographical unit with management significance, such as town, county, or watershed.

Step 7: Scenario Analysis

Finally, scenario or historic change analysis can be conducted by changing the inputs in steps 4 and 5. For future scenario analysis, this involves changing the land cover input to reflect a proposed management alternative and for historic change analysis it involves quantifying and valuing land cover changes in the past.

12.5.2 Phase 2: Identify Existing Human Community Value that Results from Ecosystem Service Value

Human communities situated in the San Bernardino Mountains, total 20 communities, consisting of approximately 54,500 resident population, increasing up to 440,000 in tourist peak seasons,[35] with a net economic value of approximately US$ 9.37 billion:

High-altitude human communities "value":

Residential property	US$ 1.9 billion
Commercial property	US$ 1.0 billion
Institutional (schools)	US$ 0.57 billion
Manufacturing	US$ 0.25 billion
Public services (fire, police)	US$ 0.35 billion
Healthcare facilities/services	US$ 0.05 billion
Tourism	US$ 0.75 billion
Infrastructure (roads, bridges, dams, utilities, sewage, man-made landscaping, street lighting, etc.)	US$ 4.5 billion
Total	US$ 9.37 billion

12.5.2.1 Human Communities in High-Altitude Ecosystem of San Bernardino Mountains

1. Lake Arrowhead: elevation of 5174 ft. (1577 m), population = 12,424
   i. The racial makeup of Lake Arrowhead was 10,729 (86.4 %) White (73.0 % non-Hispanic White)[36],95 (0.8 %) African American, 93 (0.7 %) Native American, 152 (1.2 %) Asian, 33 (0.3 %) Pacific Islander, 847 (6.8 %) from other races, and 475 (3.8 %) from two or more races. Hispanic or Latino of any race were 2709 persons (21.8 %).
2. Big Bear City: elevation of 6772 ft. (2064 m), population = 12,304
   i. The racial makeup of Big Bear City was 10,252 (83.3 %) White (75.8 % non-Hispanic White)[37], 83 (0.7 %) African American, 202 (1.6 %) Native

[35] Robinson and Harris (2006, p. 1).

[36] http://en.wikipedia.org/wiki/Lake_Arrowhead,_California#cite_note-12.

[37] http://en.wikipedia.org/wiki/Big_Bear_City,_California#cite_note-3.

American, 103 (0.8 %) Asian, 31 (0.3 %) Pacific Islander, 1089 (8.9 %) from other races, and 544 (4.4 %) from two or more races. Hispanic or Latino of any race were 2323 persons (18.9 %)

3. Crestline: elevation of 4613 ft. (1406 m), population = 10,770
4. Big Bear Lake: elevation of 6752 ft. (2,058 m), population = 5112

    i. The racial makeup of Big Bear Lake was 4204 (83.8 %) White (73.3 % non-Hispanic White)[38],22 (0.4 %) African American, 48 (1.0 %) Native American, 78 (1.6 %) Asian, 10 (0.2 %) Pacific Islander, 491 (9.8 %) from other races, and 166 (3.3 %) from two or more races. Hispanic or Latino of any race were 1076 persons (21.4 %).

5. Running Springs: elevation of 6109 ft. (1862 m), population = 4862

    i. The racial makeup of Running Springs was 4325 (89.0 %) White, 23 (0.5 %) African American, 47 (1.0 %) Native American, 50 (1.0 %) Asian, 6 (0.1 %) Pacific Islander, 146 (3.0 %) from other races, and 265 (5.5 %) from two or more races. Hispanic or Latino of any race were 695 persons (14.3 %).

6. Blue Jay: elevation of 5203 ft. (1586 m), population = 2314
7. Sugarloaf: elevation of 7096 ft. (2163 m), population = 1816

    i. The racial makeup was 61.9 % White, 1.2 % African American, 2.3 % Native American, 1.0 % Asian, 0.1 % Pacific Islander, 3.6 % from other races, and 6.3 % from two or more races. Hispanic or Latino of any race were 27.9 % of the population.

8. Forest Falls: elevation of 5341 ft. (1628 m), population = 943
9. Green Valley Lake: elevation of 7200 ft. (2195 m), population = 800
10. Arrowbear Lake: elevation of 6086 ft. (1855 m), population = 736
11. Lytle Creek: elevation of 3800 ft. (1200 m), population = 701

    i. The racial makeup of Lytle Creek was 606 (86.4 %) White, 6 (0.9 %) African American, 7 (1.0 %) Native American, 23 (3.3 %) Asian, 0 (0.0 %) Pacific Islander, 25 (3.6 %) from other races, and 34 (4.9 %) from two or more races. Hispanic or Latino of any race were 98 persons (14.0 %).

12. Cedar Glen: elevation of 5403 ft. (1647 m), population = 552, demographics: The racial makeup of the CDP was 86.6 % White, < 0.1 % African American, < 0.1 % Native American, 9.2 % Asian, 4.2 % Pacific Islander, < 0.1 % from other races, and < 0.1 % from two or more races. Hispanic or Latino of any race were < 0.1 % of the population.[39]
13. Rimforest: elevation of 5741 ft. (1750 m), population less than 100
14. Skyforest: elevation of 5741 ft. (1750 m), population less than 100

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[38] http://en.wikipedia.org/wiki/Big_Bear_Lake,_California#cite_note-8.

[39] http://en.wikipedia.org/wiki/Cedar_Glen,_California#cite_note-3.

15. Crest Park: elevation of 5630 ft. (1720 m), population less than 100
16. Twin Peaks**:** elevation of 5777 ft. (1761 m), population less than 100
17. Mountain Home Village**:** 3691 ft. (1125 m)
18. Angelus Oaks: elevation of 5800 ft. (1800 m), population = 535
19. Fawnskin: elevation of 6827 feet (2081 m). population: artist colony less than 100
20. Arrowhead Springs: elevation of 2059–3000 ft. (1145 m), population = 6

Total resident population: approximately 54,500

Total tourism population: 400,000–500,000 annually

Communities at the base of the San Bernardino Mountains which depend primarily on the high-altitude ecosystem water supply have a combined population of approximately 2,100,000,[40] providing over 700,000 jobs, and generating approximately US$ 70.9 billion in revenue:

- Manufacturing shipments: US$ 18.9 billion
- Wholesales: US$ 27.6 billion
- Retail sales: US$ 21.7 billion
- Hospitality and food services: US$ 2.7 billion

Total = US$ 70.9 billion

These urban communities cover an area of approximately 20,057 square miles (51,944 km^2) or 12.8 million acres (5.2 million ha).

12.5.3 Phase 3: Identify Climate Change Impacts, Positive and Negative, on Both Ecosystem Service Value and Human Community Value

The balance of scientific evidence suggests that there will be a significant net harmful impact on ecosystem services worldwide if global mean surface temperature increases more than 2 °C above preindustrial levels or at rates greater than 0.2 °C per decade (*medium certainty*). There is a wide band of uncertainty in the amount of warming that would result from any stabilized greenhouse gas concentration, but based on the Intergovernmental Panel on Climate Change (IPCC) projections this would require an eventual carbon dioxide (CO_2) stabilization level of less than 450 parts per million CO_2 (*medium certainty*).[41]

Climate change in our case study, the San Bernardino high-altitude ecosystem and human communities that depend on it, will trigger impacts on the ecosystem services described in detail on pp. 14–16, Step 1: Regulating Services, Cultural Services, and Supporting Services.

[40] U.S. Department of Commerce (2012).

[41] Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 31).

Much of the data assembled for the section topics below are from *Climate Change-Related Impacts on the San Diego Region by 2050*. This study considers the regional impacts due to climate change that can be expected by 2050 if current trends continue. The range of impacts presented in this study is based on projections of climate change using three climate models[42] and two emission scenarios drawn from those used by the IPCC.[43] A number of analytical models were developed and used for this study to provide quantitative estimates of the impacts where possible. For example, temperature data from the IPCC scenarios were applied to regional ecosystem models to provide information on the migration patterns of species trying to adapt to higher temperatures. These temperature data were also used to extrapolate forecasts of peak electricity demand in the region, which will be exacerbated by higher temperatures as well as the faster inland population growth where the country is hottest.[44]

For some impacts, the study has relied on a literature review and summary of the latest research in the topic of interest. For example, the increased likelihood of regional wildfires as well as the relationship of heat stress illnesses and fatalities due to rising temperatures has been based on these expert reviews. Similarly, the long-term supply issues associated with external water deliveries from the Sacramento River Delta and the Colorado River have been based on the conclusions from outside research. These water supply conclusions have been combined with an analytical extrapolation of regional water demand to develop an overall supply and demand analysis for this study.[45]

A. Climate change on ecosystem service value (ESV):

1. A changing climate will add to the stress on ecological systems in ways that may create feedback cycles with significant consequences. For example, as the amount of rainfall occurring within (and between) years changes, the effects of fragmentation on native species may be even more intense. Also, the current fire regime is changing rapidly and many species will not be able to adapt fast enough, which can lead to the extinction of native plants and animals. There is evidence pointing to nitrogen deposition as being one of the factors contributing to the recent changes of fire regimes in Southern California. Although more research is needed in this area, nitrogen deposition may contribute to greater fuel loads by facilitating the proliferation of invasive grasses and thus altering the fire cycle in the region (Allen et al. 2003). With climate change, the "climatic envelopes"[46] that species need will move due to increasing temperatures and

[42] The three models are: the National Center for Atmospheric Research's Parallel Climate Model (PCM), the National Oceanic and Atmospheric Administration's Geophysical Fluids Dynamics Laboratory (GFDL) version 2.1, and the French Centre National de Recherches Météorologiques (CNRM).

[43] The IPCC's Special Report on Emissions Scenarios (SRES) A2 and B1 scenarios.

[44] Messner et al. (2005, p. 1).

[45] Messner et al. (2005, p. 1).

[46] Locations where the temperature, moisture, and other environmental conditions are suitable for persistence of species.

more frequent fires. For many species, a changing climate is not the problem per se. The problem is the rapid rate of climate change: the envelope will shift faster than species are able to follow. For other species, the envelope may shift to areas already converted to human land use. To put the rate of temperature change for species survival into context, a 1–5 ° (0.56–2.8 °) increase by 2050 predicted by the three climate change models is 10–50 times faster than the temperature changes (2 °, or 1.1 ° per 1000 years) that occur when ice ages recede.[47]

2. California climate projections indicate forest ecosystems will be substantially affected by temperature rise and indirect climate change effects (Cayan et al. 2008a). Extended drought can stress individual trees, increase their susceptibility to insect attack and result in widespread forest decline. For example, it is thought that lowered water tables from drought and excessive groundwater pumping is causing coast Live Oaks in the Descanso area to die out as experts cannot isolate a disease or insect causing their ruin. The projected warmer winter temperatures may indirectly increase insect survival and populations, including pest species such as bark beetles that girdle and kill the trees. Forest-dependent fish and wildlife species may be lost as a result of reduced forest habitat and other indirect effect of climate change, such as drought, increased nonnative grasslands, and wildfire. Latitudinal and/or elevation range shifts in the distribution of plant and animal populations in response to climate change could be severely constrained in the county as a result of population growth and development, habitat degradation by nonnative grasses, unsuitable soils or other physical limitations (Parmesan 2006). Southern California Shrublands The results of the Center for Conservation Biology (CCB) modeling showed that southern California shrublands, in response to rising temperatures and reduced precipitation, each vegetation type moves to higher elevations where conditions are cooler and there is greater precipitation. The suitable environmental conditions for coastal sage scrub were predicted to decrease between 10 and 100 % under altered climate conditions, with the greatest reductions at higher temperatures and extremes in precipitation. Chaparral responded in a similar manner as coastal sage scrub, although higher percentages of suitable habitat remain at the elevated temperatures with current or reduced levels of precipitation. Projected increases in nonnative grasses and fire frequency also may substantially reduce the range and extent of future shrublands.
   Plant and animal species will each differ in their sensitivity to a changing climate, but the fact that they depend on each other increases the overall effects. The CCB models predicting suitable habitat for the Quino Checkerspot butterfly and California Gnatcatcher, when in association with plant species, were compared with predictions from models that included only climate variables and did not consider species associations. It was found that when vegetation, shrub, or host plant species were included in the animal models, potential habitat for the butterfly and songbird were reduced by 68–100 % relative to the climate-only models under altered climate conditions.[48]

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[47] Messner et al. (2005, p. 24).

[48] Messner et al. (2005, pp. 24–25).

3. Extinction of fauna species[49]

   i. Fauna species at risk: San Bernardino flying squirrel, California Spotted Owl, Mountain yellow-legged frog, Southern Rubber Boa, and Andrew's marbled butterfly.[50]

4. Extinction of flora species and emergence of new, climate-adapted species[51]

   i. Flora species are listed as[52][53]:

      1. *Sensitive plant list*: There are more than 85 species of sensitive plants.[54] They include Colville's Dwarf-Abronia, Parish's Rock-cress, Yellow Owl's Clover, Abram's Live-Forever, Parish's Alumroot, Fuzzy Rat-Tails, Lemon Lily, Baldwin Lake Linanthus, Purple Mimulus, Windows Phacelia and Pine-Green Gentian.
      2. *Watch list*: Bear Valley Woolypod of the pea family, Woolly Sunflower, Humboldt Lily, Laguna Mountains Jewel Flower, a member of the mustard family and Lemmon's *Syntrichopappus*, a variety of sunflower. Watch list plants are those that need to be observed to make certain they are not threatened or endangered.
      3. *Federally threatened list*: Three plants in the San Bernardino Mountains are on the federal threatened species list, according to the National Parks Service. They include Bear Valley Sandwort, a member of the pink family; Ashy-Grey Paintbrush, part of the figwort family; and Kennedy's Buckwheat which is, of course, a member of the buckwheat family. These plants are considered dangerously close to extinction unless protected from human activity and repopulated. *Federally endangered list*: Endangered plant species are on the verge of extinction and consequently require extraordinary management and guidance on federal lands as well as a recovery plan. Three plants in the San Bernardino Mountains are on the federal endangered species list. They include San Bernardino Mountains bladderpod and Slender-Petaled Mustard, both of the mustard family, and Bird-footed Checkerbloom, a member of the mallow family.

5. *Temperature change*: Mountains are likely to warm 4.5–5.5 °F. The occurrence of "extreme heat days," days when temperatures exceed 95 °F, is expected to increase substantially. Mountain areas will see extreme hot days increase by 4.5–6 times the current number. The biggest surprise from the more detailed modeling is that the coasts and mountains are warming a lot faster than anyone suspected.

[49] Currently, there are approximately 440 species of fauna. U.S. Forest Service (2009a).

[50] "Endangered Species". *Mountains Group-San Gorgonio Chapter*. Sierra Club.

[51] Currently, there are 1600 species of flora. Grinnell (1908).

[52] Douglas Hawk, eHOW, Demand Media Inc., September 22, 2011.

[53] US Fish & Wildlife Service, US Department of the Interior, March 27, 2013.

[54] U.S. Department of Agriculture, Forest Service (2010).

The tops of nearby mountains like the San Bernardinos, which currently have ski areas like Big Bear, will warm faster than any other place in the Los Angeles area. The coasts, too, will be far warmer than had previously been expected.[55]

6. *Rainfall change*: Precipitation in the region will retain its Mediterranean pattern, with winters receiving the bulk of the year's rainfall, and summers being dry. Models lack consensus on whether it will be drier or wetter overall, but because of warming and effectively earlier summer conditions, there is evidence that the area's landscape will fall into hydrological deficit (drought) more often than it has historically.[56] *Drought*: One important aspect of all of the climate model projected simulations is that the high degree of variability of annual precipitation that the region has historically experienced will prevail during the next five decades. This suggests that the region will remain highly vulnerable to drought.[57]
7. *Snowfall change*: By 2050, the San Bernardino mountains may see a reduction in snowfall up to 42 % of their annual averages. If immediate efforts are made to substantively reduce emissions through mitigation, mid-century loss of snow will be limited to 31 %. However, if emissions are not curbed, the mountains will lose 66 % of their snowfall by the end of the century, compared with present day.
8. *Water resource change*: The effects of climate change on water demand are likely to reflect both warming and drying trends. Climate-change projections for the southwestern USA indicate that by 2050, runoff and ground water could decline by an average of about 7 in./year over the entire Southwest (Seager et al. 2007; Milly et al. 2005). As noted earlier, elevated greenhouse gas levels are expected to produce temperature increases of 1.5–4.5 °F (0.8–2.5 °C) over Southern California by the mid-twenty-first century. More frequent and drier (20 % drier) drought years are also projected by the early twenty-first century, assuming increased ENSO[58] intensity. The model results shows droughts becoming 50 % more common during the 2000–2049 period than during the 1950–1999 period.[59] Drought and soil moisture retention will negatively impact water levels in:

   i. Lakes/dams
   ii. Reservoirs/dams
   iii. Streams
   iv. Wells

9. *Wildfire change*: The frequency of fire incidents and their devastating impacts on the residents of the region has increased in direct proportion to human population growth since the vast majority of ignitions are caused by human

[55] http://green.blogs.nytimes.com/2012/07/05/district-by-district-climate-change-in-los-angeles/?_r=0, Kaufman (2013).

[56] Messner et al. (2005, p. 38).

[57] Messner et al. (2005, p. 14).

[58] El Nino/Southern Oscillation (ENSO).

[59] Messner et al. (2005, p. 21).

Fig. 12.15 Firefighting and aftermath of wildfires in San Bernardino Mountains (© USDA 2012)

activities. It is likely that the changes in climate due to the warming of the region will increase the frequency and intensity of fires even more, making the region more vulnerable to devastating fires. Extended drought conditions forecasted by climate models in the coming decades are expected to increase the likelihood of large wildfires. A past study of the western USA has shown (Westerling et al. 2006) that large wildfire frequency and longer wildfire durations increased in the mid-1980s when there was a marked increase in spring temperatures, a decrease in summer precipitation, drier vegetation and longer fire seasons. A more recent study (Spracklen et al. 2008) explores these relationships to 2050 using temperature and precipitation data from a global climate model (GISS).[60] This study suggests that 42 % more California Coastal Shrub acreage will burn in the decade around 2050 as compared to present trends and that overall, 54 % more acreage in the western USA will burn compared to present (Fig. 12.15).[61]

B. Climate change on human communities will have the following impacts:

1. *Population shifts*

    1. As the region's population grows, it will also become older. Approximately, one quarter of the region's current population is baby boomers, the large cohort born between 1946 and 1964. Their presence helps increase the median age in the region from 33.7 years in 2004 to 39 years in 2030, an increase of 16 %. Dynamic changes in the region's age structure will continue to occur from 2030 and 2050, albeit at a slower pace than seen in the 2030 forecast. Between 2030 and 2050, the number of people age 65 and older is estimated to increase by 35 %, compared to an increase of 14 % for the overall population. Age groups under 18, and between 18 and 64, will grow more slowly—at around 10 % each. By 2050, almost one quarter of the region's residents (over 1,000,000) will be age 65 and older, with over half being older than age 41. The aging population of the region will be more vulnerable to the public health impacts of climate change, including increased heat waves and air pollution.[62]

[60] Goddard Institute for Space Studies (GISS).

[61] Messner et al. (2005, p. 22).

[62] Messner et al. (2005, p. 2).

2. Scenario 1: Climate change impacts may result in human migration away from the mountains to more convenient, reliable, cheaper, safer, and less risk amenities. Human population decrease in ecosystem region will benefit the restoration of ecosystem services, even if these services are new due to climate change, since man-made exploitation or "footprint" on the ecosystem would decrease. For example, fewer automobiles from tourism would reduce air and noise pollution, fewer tourists and residents in mountain communities would result in reduced consumption of fossil fuels, water, reduced solid waste and sewage. Wildlife species would begin to recover, flora species may expand with less interference from human exploitation
3. Scenario 2: Climate change impacts may result in increased human populations in the mountains. For example, lower elevation communities and urban cities will increase in size creating urban congestion, air and noise pollution, restrictions on water and energy consumption, minimal private land, crowded residential neighborhoods, crowded schools, congested traffic, and minimal "natural" environments. Consequently, many people will seek refuge from urban congestion in the mountains, despite the risks, costs, and inconveniences. They will adjust their lifestyles to the ecosystem impacts from climate change. The lifestyle adaptation will outweigh the negative alternatives of living in lower elevations. Access to water, fresher and cooler air, protected natural forests, quieter environment, and less congestion will be worth it.
4. Tourism
    1. Decrease in tourism may occur due to cost of transportation fuel, traffic congestion, and poor economy.
    2. Increase in tourism may occur due to desire to seek healthier environment (clean air, cooler temperatures, closeness to "nature," recreation, and "get-away" from urban congestion, noise, and pollution.

2. *Public health shifts*: There are many potential public health issues that are likely to affect the region in 2050, both directly and indirectly. Projections of a growing and aging population with changing ethnic profiles suggest a larger number of people will be vulnerable to environmental health risks, and the projections for climate change indicate more stressful conditions facing vulnerable populations. Specific impacts include: (1) increased heat waves, creating a significant risk of adverse health effects and heat-related mortality; (2) increased exposure to air pollution resulting in adverse health effects, including exacerbation of asthma and other respiratory diseases, cardiac effects, and mortality; (3) increasing incidence of wildfire, which will contribute to direct injuries and mortality as well as indirect health effects of air pollution; and (4) increases in the levels of exposure to vector-borne or infectious diseases—potential increases in West Nile Virus and hantavirus will require particular attention and increased medical resources to address. All of the above impacts have a magnified effect on an aging population base and will therefore require increased efforts and resources to effectively manage.[63]

[63] Messner et al. (2005, pp. 41–42).

1. *Extreme heat*: Heat waves have claimed more lives over the past 15 years than all other declared disaster events combined in California, and heat waves are expected to increase in frequency, magnitude and duration in the region over the next 50 years. Public health risks around extreme heat are not equal; certain individuals, populations, and communities are at greater risk than others. A recent analysis of temperatures during summers with no heat waves (1999–2003) found a 3 % increase in deaths in any given day for a 10 °F (5.6 °C) increase in temperature (including humidity; Basu et al. unpublished.). Factors that should be considered when identifying community-level risk include the incidence of relatively high percentages of: children under 5 years of age and elderly people 65 and over; chronically ill persons (especially those suffering cardiovascular or respiratory conditions); and socially isolated individuals. In 2050, there will be one million seniors 65 years and older in the region, roughly equal to nearly one quarter of the region's total population. The aging population of the region will likely face more mortality events associated with an increase in temperature due to climate change.[64]
2. *Disease*: Climate change could increase the risk of certain vector-borne diseases, while decreasing the risk of others. The occurrence of vector-borne disease is influenced by a variety of factors. Prevailing temperature influences the rate of development of larvae of some vectors, as well as the rate of development of the infectious agent in the vector. Humidity and rainfall patterns affect both the composition and abundance of arthropod vectors (mosquitoes, fleas, ticks, etc.), as well as animal hosts (Lang 2004).[65] Behavior patterns of hosts, such as indoor living, and vector preferences for particular hosts and periods of peak activity, also influence transmission opportunities. The region will experience increased public health risks from mosquito-transmitted West Nile Virus (Dudley et al. 2009) assuming more intense El Niño cycles (Anyamba et al. 2006) and rodent-transmitted hantavirus (Yates et al. 2002), and higher temperatures predicted for the region could facilitate the local establishment of tropical vector-borne diseases such as malaria and dengue fever, while reducing public health risks from the endemic mosquito-transmitted diseases Western Equine Encephalitis and St. Louis Encephalitis (Gubler et al. 2001). Climate warming effects on the geographic and altitudinal ranges and population densities of rodent hosts and flea vectors will alter the distribution of high-risk areas for plague (Yersinia pestis) in the region (Lang 1996; 2004).[66] Predicted future increased residential development and recreational activities within the unincorporated areas of the region due to population growth, which will increase the potential for contact between humans and wildlife disease hosts and vectors, may result in higher public health risks from diseases transmitted by rodents and rabbits such as tularemia, plague, and hantavirus (Smith 1992).[67]

[64] Messner et al. (2005, pp. 26–27).

[65] www.sove.org/Journal%20PDF/December%202004/5Lang%2003-44.pdf.

[66] www.sove.org/Journal%20PDF/December%202004/5Lang%2003-44.pdf.

[67] Smith and Mendelsohn (2006).

3. *Economic shifts*

   1. Tourism will still represent main source of revenue for mountain communities
   2. The cost of water will be adversely affected both by increases in the costs of water imports and increases in demand, anticipated as a result of climate change. Currently, the cost of supplying additional water to the region—which can be inferred from the cost of new desalination and reclamation projects—is between US$ 600 and 1800/acre-ft., depending on the water source. This cost may rise significantly by 2050 as less expensive ways to increase water supply are exhausted. Continued growth in Los Angeles, Arizona, Las Vegas, and the Central Valley is likely to increase competition for the same imported water supplies, with the potential to drive up prices as purchase agreements are renegotiated in the future. Aggressive actions to plan for future water supplies as they vary with climate change and to curb demand through conservation measures will have significant economic benefits as well as overall improvements in the reliability of water deliveries to the public.[68]
   3. The cost of the 2007 wildfires in the region was estimated at nearly US$ 2 billion for losses in residential and commercial properties (Nash in press). In addition to the direct costs, many private firms and public agencies are forced to shut down during a large-scale wildfire event. A complete three-day shutdown costs roughly US$ 1.5 billion.[69] Therefore, one extra large-scale wildfire due to climate change can have a major impact on the economy due to productivity losses.
   4. Californians experience the worst air quality in the nation, resulting in yearly economic costs of approximately US$ 71 billion (US$ 36–136 billion), with about US$ 2.2 billion (US$ 1.5–2.8 billion) associated with hospitalizations and medical treatment of illnesses related to air pollution exposure.[70] Deteriorating air quality from increases in ambient ozone levels as well as possible increases of particulate matter (PM) levels in some scenarios will push these costs even higher. Local and regional emission mitigation activities will be essential in reducing these costs and improving regional public health.

4. *Pollution shifts*

   1. Air quality: An increase in hot, sunny days due to climate change causing increased population exposure to ground-level ozone has been projected for the region in the year 2050. In addition to potential increases in ozone levels, there will be increased stress from extreme heat days, coupled with an increase in the number of vulnerable people present within the region. These changes are likely to present a significant public health and economic impact.[71] Wildfires can be a significant contributor to air pollution in both urban and rural areas, and have the potential to significantly impact public health through particulates and volatile organic compounds in smoke plumes.

[68] Messner et al. (2005, p. 40).

[69] Messner et al. (2005, p. 40).

[70] Messner et al. (2005, p. 42).

[71] Messner et al. (2005, p. 28).

Wildfire smoke contains numerous primary and secondary pollutants, including particulates, polycyclic aromatic hydrocarbons, carbon monoxide, aldehydes, organic compounds, gases, and inorganic materials with toxicological hazard potentials (Künzli et al. 2006). Future land use and climate change will exacerbate the risk of wildfires as a result of the alteration of fire regimes in the county. Fires also create secondary effects on morbidity as the result of increased air particulates that can worsen lung disease and other respiratory conditions. People most at risk of experiencing adverse effects related to wildfires are children and individuals with existing cardiopulmonary disease, and that risk seems to increase with advancing age.[72]

5. *Infrastructure shifts*: increase stress on infrastructure

    1. Electricity: The forecast shows a dramatic increase of 60–75 % in peak electricity demand by 2050, an increase of more than 2500 MW from present levels. The differences between the models account for roughly 7 % of the total, or approximately 400 MW. The "base case" on the graph shows what peak demand would be if temperatures did not increase (i.e., demand based on population growth alone).

       Annual consumption trends for electricity: There is a nominal difference in the forecasts based on the model and scenario. This means that assumptions about electricity consumption in the forecasting model are primarily population-dependent and only marginally temperature-dependent for estimating annual electric consumption. Overall annual electricity consumption is expected to increase of 60–62 % by 2050 compared to current demand. Rising temperatures account for approximately 2 % of the increase in consumption.[73] Demand for electricity is projected to increase significantly by 2050. That increase will be largely driven by population increases, augmented by increased average and peak temperatures, especially in inland areas where population growth rates are highest. The main climate impact on electricity demand and associated supply issues will be the increased need for summer cooling. Overall, peak demand for electricity and annual electricity consumption will rise dramatically in the region by 2050. Annual electricity consumption is expected to increase more than 60 %. That will push consumption from the current level of approximately 20,000 gigawatt-hours (GWh to more than 32,000 GWh in 2050. While population growth is an important contributor to increased demand, warmer temperatures are expected to push total energy consumption up to 2 % points above the population-driven change by 2050. Similarly, peak electric demand is expected to increase by over 70 %, from approximately 3700 MW to as much as 6400 MW in 2050. Increased average and peak temperatures (i.e., climate-driven changes) are projected to account for approximately 7 % of the total increase in peak demand.[74]

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[72] Messner et al. (2005, pp. 29–30).

[73] Messner et al. (2005, p. 34).

[74] Messner et al. (2005, pp. 42–43).

2. Fossil fuels (natural gas, transportation fuel) and renewable energy (solar electricity, solar hot water, wind electricity, geothermal): remote mountain communities may discover that renewable energy sources, plus energy conservation, will be more reliable and less expensive.

   a. Extreme temperature events and impact on system reliability: Peak demand will be even more challenging to deal with under future climate scenarios because of the increased frequency of extreme heat events. To avoid reliability problems and increased outages, the electric utility will need to make additional investments and customers will need to modify consumption patterns in order to reduce peak summer electricity demand. In general terms, the analysis of the climate models and extreme temperature events shows that there will be a three-month expansion of higher-temperature events as well as an increased frequency of events. In other words, the period when high-temperature days are most frequent, currently between June and September, will expand to May through November. Early November will "feel" like September currently does.
   b. Decreased summertime generation capacity: Summertime, when demand is highest, is also the time when operating efficiency is lower and line losses increase—both due to temperature effects. This will result in further need for utilities to purchase or build additional power supplies. Further, transmission line congestion is worst during times of peak demand, which will exacerbate delivery problems unless utility investments keep pace with these effects.
   c. Thermal generator efficiency: The efficiency of thermal power generators, including fossil fuel as well as nuclear-fired units, goes down when air temperature goes up. Higher outdoor air temperatures reduce the efficiency and capacity rating of natural gas and oil units by reducing the ratio of high and low temperatures in the power cycle.
   d. Wind generation: The availability of wind power may also be affected by climate change, although projected climate impacts on wind are highly uncertain at this time. Further research in this area is needed because changes in wind resources are not currently modeled in the global climate scenarios. The US Climate Science Program predicted that overall wind-power generation would decrease in the mountain areas of the West, but could increase in California (US Climate Change Science Program 2007).[75] New research could provide more specificity with regard to both the location of impacts on wind resources and the timing of those effects, so that utilities may consider wind's impact on generation in the context of both installed capacity and imported energy.
   e. Transmission line losses: Transmission line losses may increase as a result of climate change, although there is a need for further research in this area. One study quantified temperature impacts on electricity transmission line losses, noting that "electric transmission lines have greater resistance in warmer temperatures, and thus climate change will result in

[75] Available at: www.ornl.gov/sci/sap_4.5/energy_impacts/sap4_5final_rvwdrft.pdf.

increased line losses (Feenstra et al. 1998).[76] A separate concern is line sag. As demand increases during hot weather, transmission line conductor temperatures increase, which causes the lines to stretch and sag. If a line sags into an object such as a tree, the current can be discharged to the ground, causing a short circuit that could initiate a major power outage. However, it is conductor temperature (a function of load) that is the main cause of sagging power lines. Currently, there are insufficient data to conclude that ambient temperature increases of a few degrees would have a significant impact on line sag.[77]

3. Potable water: Economic value of water resources will increase, resulting in tighter controls and regulations over water acquisition, storage, and distribution. Prioritization of water will be established: food (agriculture irrigation), drinking (potable water), human services (healthcare), recreation (pools), aesthetics (fountains). Seawater desalination will be considered an option to reduce potable water demand from high-altitude water resources, but will increase regional power demand. Other regional options such as recycling and local groundwater are less energy intensive, 400 and 570 kWh/af, respectively, according to a Pacific Institute study, *Energy Down the Drain* (Cohen et al. 2004). That study concluded that satisfying future growth in water demand in the region via conservation would reduce the overall energy intensity of the water supply by 13 %. In comparison, satisfying growth in water demand via recycling would reduce overall energy intensity by only 4 %, while using seawater desalination to satisfy growth would increase overall energy intensity by 5 %. This emphasizes the overall energy savings of conservation versus other regional alternatives. The energy savings will also result in less overall GHG emissions from the utility sources providing the power.[78]
4. Greywater**:** Reuse and harvesting of greywater will be maximized for agriculture irrigation, firefighting, landscape irrigation, flushing toilets, as an example.

   Due to critically dry conditions during 2007 and 2008, the government of California has declared a statewide drought. Local agencies have developed a drought management plan that targets 10–40 % reductions in customer consumption, depending on the level of drought intensity. One of the adopted initiatives under this program is the “20 gallon challenge,” which calls for a variety of end user voluntary conservation steps. This challenge targets 10 % reductions in consumption (roughly 20 gallons per person) in the current drought. Current evidence suggests that a much smaller reduction is being achieved despite public advertising and awareness campaigns. Successfully achieving the higher reduction figures (40 % or more) will rely on mandatory control measures, which will become increasingly necessary if voluntary measures have limited effectiveness.[79]

[76] Stern et al. (1998).

[77] Messner et al. (2005, pp. 35–36).

[78] Messner et al. (2005, p. 35).

[79] Messner et al. (2005, p. 39).

5. Wastewater: Sewage, or “blackwater,” will be processed from primary, secondary, and tertiary treatments so that it produces useful “greywater.” In some instances, it may even be processed into potable water through UV, ozone, and carbon filtration.

6. Ecosystem exploitation shifts: As a result of growing population, the future demand on ecosystem services will increase significantly. There will be a shift in public policy and consumer behavior (voluntarily or regulated) to optimize key ecosystem services as noted earlier: (a) regulating services, (b) cultural services, and (c) supporting services. Greater respect will shift human community attitudes towards conservation and restoration of ecosystem services.
7. Natural capital investment shifts: As a result of behavioral attitude changes where human communities recognize ecosystem services (but, if not, government policy will regulate behavior), capital investments will be targeted at comprehensive and effective programs that preserve, conserve, restore, and sustain ecosystem services.

12.5.4 Phase 4: Identify Paths Forward to Reduce Negative Impacts and/or How Human Communities Must Adapt to Climate Change Impacts

1. Policy shifts: Public decision makers and agencies must keep moving in a common direction on understanding the climate forecasts for the region, which in turn should facilitate better joint planning. For example, fire protection agencies, utility planners, and public health planners should have a common understanding of temperature increase expected for the region. Likewise, water agencies and fire prevention agencies should have a uniform understanding about the likelihood of droughts and precipitation patterns. Land use planning agencies will have to deal with the combined challenges of sea level rise in coastal areas, increasing fragmentation of ecosystems, as well as mitigation measures to address local emissions that could require increasing future population centers around transportation corridors.[80]

2. Behavioral shifts**:** Human behavior must change. A few examples:

Agriculture

- Remove production subsidies that have adverse economic, social, and environmental effects.
- Investment in, and diffusion of, agricultural science and technology that can sustain the necessary increase of food supply without harmful tradeoffs involving excessive use of water, nutrients, or pesticides.
- Encourage new innovations in food production, including hydroponics, aeroponics, aquaculture, vertical farming; i.e., soil-less agriculture.

[80] Messner et al. (2005, p. 36).

- Encourage locally grown produce to reduce transportation costs and pollution. Refer to USGBC's (United States Green Building Council) Leadership in Energy and Environmental Design (LEED)-rating system, as an example.

Water

- Establish and enforce fees for ecosystem services provided by watersheds.
- Increase transparency of information regarding water management and improved representation of marginalized stakeholders.
- Establish water markets that incorporate bioregional context; i.e., balance water resources taken from one bioregion and consumed in another.
- Review options to dams and levees for flood control by evaluating ecosystem services solutions.
- Invest in science and technology to increase the efficiency of water use in agriculture (see above).
- Follow "green" building rating systems that address water conservation guidelines in buildings and man-made landscapes.
- Promote the use of "greywater" to replace potable water uses, such as irrigation and flushing toilets.

Forestry

- Enforce sustainable forest management practices in financial institutions, trade rules, global environment programs, and global security decision making.
- Support initiatives for sustainable use of forest products. Refer to "green" building rating systems for guidelines.[81]
- Reform forest governance and development of country-led, strategically focused national forest programs negotiated by stakeholders.

The millennium ecosystem assessment report outlines six major sectors that are necessary to address the viability of ecosystem services long term.[82]

- Institutions and governance: Changes in institutional and environmental governance frameworks are sometimes required in order to create the enabling conditions for effective management of ecosystems, while in other cases existing institutions could meet these needs but face significant barriers.

  a. Integration of ecosystem management goals within other sectors and within broader development planning frameworks.
  b. Increased coordination among multilateral environmental agreements and between environmental agreements and other international economic and social institutions.
  c. Increased transparency and accountability of government and private-sector performance in decisions that affect ecosystems, including through greater involvement of concerned stakeholders in decision making.
  d. Development of institutions that devolve (or centralize) decision making to meet management needs while ensuring effective coordination across scales.

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[81] USGBC LEED, ESTIDAMA, QSAS, GREEN STAR, BREEAM are a few of the green building rating programs worldwide.

[82] Millennium Ecosystem Assessment, World Resources Institute (2005a, pp. 93–100).

e. Development of institutions to regulate interactions between markets and ecosystems.
f. Development of institutional frameworks that promote a shift from highly sectoral resource management approaches to more integrated approaches.

- Economics and incentives: Economic and financial interventions provide powerful instruments to regulate the use of ecosystem goods and services.

  a. Elimination of subsidies that promote excessive use of ecosystem services (and, where possible, transfer of these subsidies to payments for nonmarketed ecosystem services)
  b. Greater use of economic instruments and market-based approaches in the management of ecosystem services:
     1. Taxes or user fees for activities with "external" costs
     2. Creation of markets, including through cap-and-trade systems.
     3. Payment for ecosystem services.
     4. Mechanisms to enable consumer preferences to be expressed through markets.

- Social and behavioral responses: Social and behavioral responses—including population policy; public education; empowerment of communities, women, and youth; and civil society actions—can be instrumental in responding to ecosystem degradation.

  a. Measures to reduce aggregate consumption of unsustainably managed ecosystem services
  b. Communication and education
  c. Empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and young people
- Technological responses: Given the growing demands for ecosystem services and other increased pressures on ecosystems, the development and diffusion of technologies designed to increase the efficiency of resource use or reduce the impacts of drivers such as climate change and nutrient loading are essential.

  a. Promotion of technologies that increase crop yields without any harmful impacts related to water, nutrient, and pesticide use
  b. Restoration of ecosystem services
  c. Promotion of technologies to increase energy efficiency and reduce greenhouse gas emissions

- Knowledge and cognitive responses: Effective management of ecosystems is constrained both by a lack of knowledge and information concerning different aspects of ecosystems and by the failure to use adequately the information that does exist in support of management decisions.

  a. Incorporate both the market and nonmarket values of ecosystems in resource management and investment decisions

Fig. 12.16 Arrowhead Springs seen from the City of San Bernardino. (©Paul Bierman-Lytle, 2005)

b. Use of all relevant forms of knowledge and information in assessments and decision-making, including traditional and practitioners' knowledge
c. Enhance and sustain human and institutional capacity for assessing the consequences of ecosystem change for human well-being and acting on such assessments

- Design of effective decision-making processes**:** Decisions affecting ecosystems and their services can be improved by changing the processes used to reach those decisions.

a. Use the best available information, including considerations of the value of both marketed and nonmarketed ecosystem services.
b. Ensure transparency and the effective and informed participation of important stakeholders.
c. Recognize that not all values at stake can be quantified, and thus quantification can provide a false objectivity in decision processes that have significant subjective elements.
d. Strive for efficiency, but not at the expense of effectiveness.
e. Consider equity and vulnerability in terms of the distribution of costs and benefits.
f. Ensure accountability and provide for regular monitoring and evaluation.
g. Consider cumulative and cross-scale effects and, in particular, assess trade-offs across different ecosystem services (Fig. 12.16).

12.5.5 Case Study: Arrowhead Springs

The current "business-as-usual" trend of human communities who reside in the high-altitude ecosystem and those communities at lower elevations that depend on ecosystem services does not bode well for the social and behavioral adaptation that is needed to prepare for climate change impacts. However, pressure on regional and local policies and regulations to address ecosystem services protection and

Fig. 12.17 One-thousand nine-hundred and sixteen-acre (775.4 ha) site boundaries. (© Paul Bierman-Lytle, 2005)

restoration is mounting. Examples include tougher building codes that target water and energy conservation, real estate development requirements that must ensure water supply for 25 years, use of drought-resistant plant species, CO_2 emission controls, and wider use of "greywater." "Sustainable development" and "green" buildings are strategies commonly accepted as desirable, and often incorporated in city planning and building guidelines and codes.

One case study exemplifies a positive shift in attitudes toward ecosystem services. Situated in the San Bernardino high-altitude ecosystem, the Arrowhead Springs community plans to be a prototype sustainable development that demonstrates how human communities can contribute to ecosystem sustainability while improving human lifestyle, culture, and increasing economic vitality (Fig. 12.17).

Arrowhead Springs encompasses 1916 acres (775.4 ha). The community has proposed the following development guidelines and objectives.

- Prepare the necessary framework for the community to be 100 % off the grid. In other words, establish design guidelines for all buildings, existing and new, to be self-reliant, self-sufficient with regard to energy, potable water, solid waste conversion, on-site transportation, communications, and security. With the exception of food independence, all utilities and infrastructure should seek an "ecosystems," or "system of systems," approach to being interdependent and independent from external resources.
- Dedicate land area for a ground-mounted solar farm with capacity to provide 100 % of the community's electricity requirements. Maximize renewable energy sources: solar, wind, hydroelectric, biofuels, and geothermal. Electricity demand for the project will require installation of a 10-MW solar electric farm, covering approximately 50 acres (20 ha) if ground-mounted. If installed over parking lots, land area could be reduced, but cost of the solar array would increase (Figs. 12.18, and 12.19).

Fig. 12.18 Ground-mounted solar photo-voltaic panels. (© University of Washington Bothell, 2013)

Fig. 12.19 Solar PV shades parking lot in Las Vegas. (©Solar Done Right, 2013). *PV* photovoltaic

- All existing and new buildings will be high-performance, integrating "deep" energy and water system solutions that are plugged into a "smart grid" integrated utility and infrastructure. Reduce water consumption and reconstitute and reuse all water resources for maximum value.
- Establish an extensive remote sensing management program that monitors the health of biodiversity, flora and fauna, on the property, so that forecasting of the ecosystem services can be observed and adapted to. Consistently and proactively manage, monitor, assess all natural capital assets on an enduring basis; and adapt human response and development to all dynamic shifts encountered or predicted (Figs. 12.20, 12.21, and 12.22).
- Incorporate commercial development activities such that each complements the ecosystem services. For example, wellness spa resorts can feature the natural mineral springs and geothermal waters as traditionally used. Hot springs, steam caves, mud baths, and spring water have historically made the site a destination for Native Americans, tourists and Hollywood celebrities in the 1940s to 1960s. The US Navy, during World War II (WWII), converted the spa resort into a hospital and recovery center (Fig. 12.23).

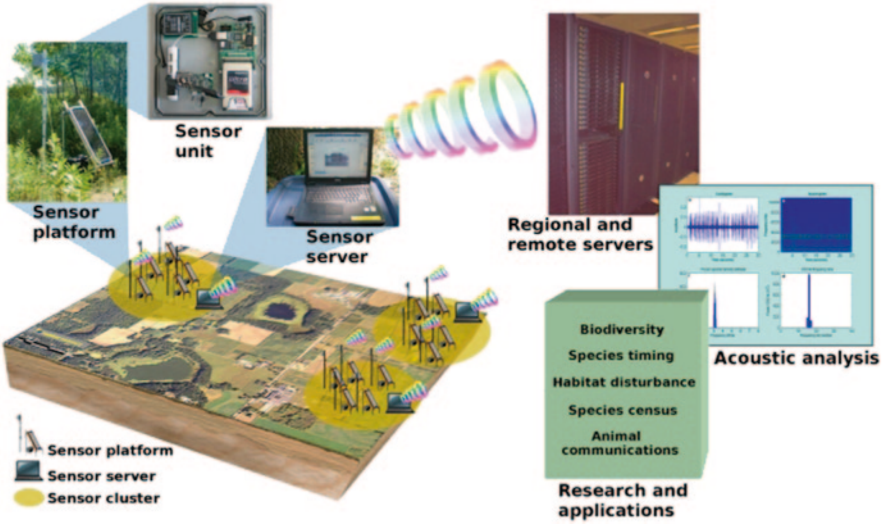

Fig. 12.20 © Remote Environmental Assessment Laboratory 2008

Fig. 12.21 Student prepares a wireless remote sensor. (© Kathy Szlavecz 2007)

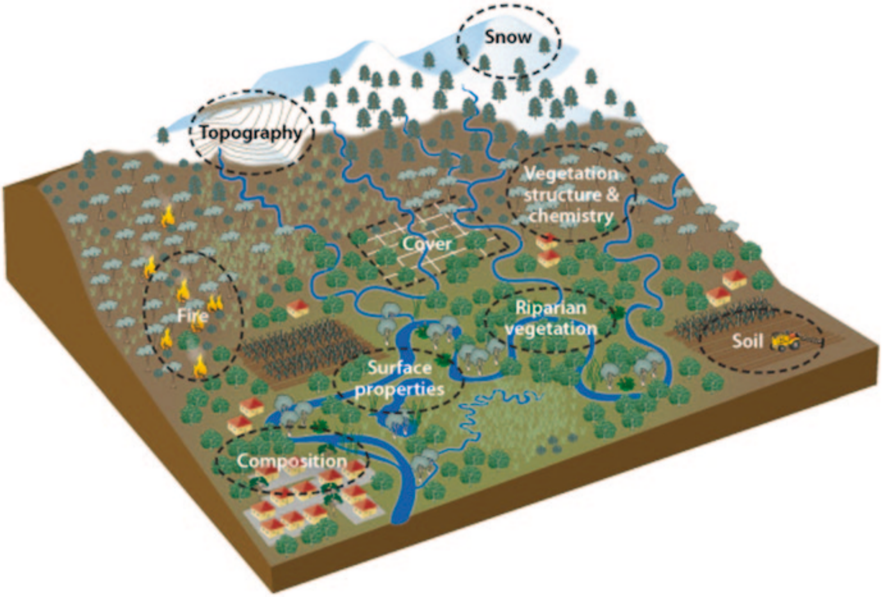

Fig. 12.22 © Remote Environmental Assessment Laboratory 2008

Fig. 12.23 Arrowhead Springs historic spa (1940s) and today. (© Arrowhead Springs 2012)

- An adventure sports park for recreation, training, and coaching is proposed for the property. Some 150 sports, including 50 on land, 50 in water, and 50 in the air, will optimize the mountainous terrain and high elevations. Promoting health and fitness, this new type of "theme" park encourages sustainable use of the natural landscapes, creates a minimal built footprint, while establishing a strong revenue source for the community. Prove that sustainability solutions are profitable, so that more communities will adopt models of sustainable development (Fig. 12.24).
- Optimize carbon sequestration through insightful land management (Fig. 12.25)

Fig. 12.24 Activities include biking, animal tracking, and bird watching. (© Arrowhead Springs 2005)

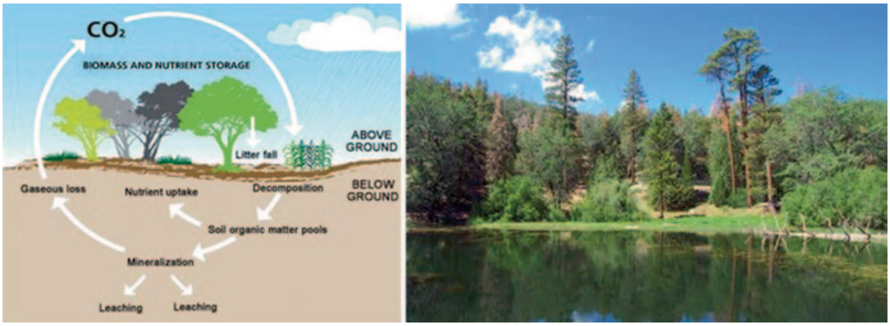

Fig. 12.25 San Bernardino Mountain forests provide significant carbon sequestration. (© Arrowhead Springs 2009)

- Integrate and embed natural capital in all economic enterprises that result in a balance or nurturing of natural capital assets versus exploitation.[83]
- Natural capital declaration: The natural capital declaration (NCD) is a finance-led initiative through which financial institutions commit to:
  - Understand the impacts and dependencies of financial institutions on natural capital (directly and through customers) which can translate into material risks or opportunities;
  - Embed natural capital considerations in financial products and services;
  - Work towards a global consensus on integrated reporting and disclosure;
  - Work towards a global consensus for the integration of natural capital in private sector accounting and decision making (Fig. 12.26).

12.5.5.1 Integrated Intelligent Infrastructure Authority

One of the key commercial innovations at Arrowhead Springs is the formation of a comprehensive integrated utility management company. The mission of this company is to maximize efficiencies of all utilities and infrastructure using "intelligent" telecommunications, sensors, and monitoring. This management company will operate

[83] Natural Capital Declaration (2012).

Fig. 12.26 Commercial ventures include hydroponic and aquaculture food production, ecological sewage treatment (©TerraSave 2012), solar/hybrid powered transportation. (©Arrowhead Springs 2012)

out of a state-of-the-art Central Command and Communications Control Center (C5) where site-wide ecosystem services and human community services interface.

The C5 manages all Arrowhead Springs property utilities (on-site and "at gate"), infrastructure, and 1444 acres (580 ha) of non-buildable land. Assets include:

1. Existing ecosystem assets and services, including adjacent land areas
    a. Flora
    b. Fauna
    c. Natural springs and wells
    d. Geothermal springs
    e. Minerals
2. Climate monitoring (precipitation, temperature)
3. Air quality
4. Noise pollution
5. Wildfire prevention
6. Existing sewage treatment plant
7. Existing man-made lakes and reservoirs
8. Existing fiber optics
9. Existing telephone/telecom services
10. Existing roads, surfaced and non-surfaced
11. Existing landscaping and irrigation network
12. Existing fire controls
13. Existing maintenance equipment and buildings

In addition, Arrowhead Springs plans to establish Arrowhead Springs Development Association (ASDA), a nonprofit company. This nonprofit organization establishes the fee tariff structure for all infrastructure used by on-site tenants, including:

14. Electricity
15. Geothermal energy for hot water, heating, and A/C
16. Spring water/potable water
17. Grey water used for irrigation and fire controls
18. Sewage/wastewater treatment plant on-site
19. Solid waste management: removal and conversion to electricity on-site

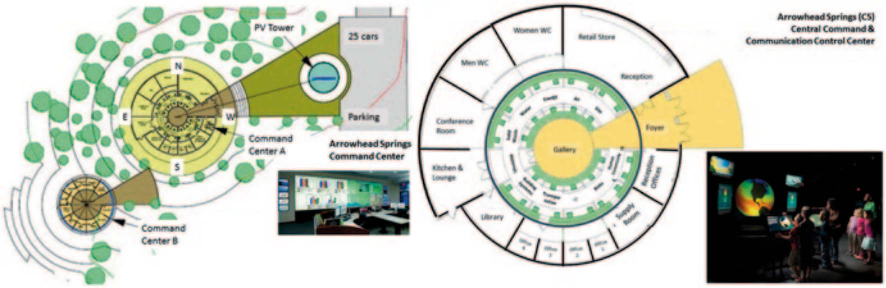

Fig. 12.27 Arrowhead Springs Central Command and Communications Control Center (C5). (© Paul Bierman-Lytle 2005)

Fig. 12.28 Arrowhead Springs master plan layout of commercial center. (© Paul Bierman-Lytle 2005)

20. Recycling center
21. On-site and off-site eco-transportation: bus service to/from airports, regional hotels, metro train station; on-site vehicles (lease or purchase), including golf carts, segways, multiple passenger trams/buses, limousine, electric bike program, etc.
22. Landscaping and irrigation and maintenance
23. Streets, paved, and unpaved
24. Parking and parking structures
25. Street lighting
26. Security lighting
27. Security (on-site police and celebrity guard protection services)
28. Fire Protection (on-site fire station)
29. Wildlife habitat management and control (Figs. 12.27, and 12.28)

12.5.5.2 Integrated Intelligent Infrastructure Methodology

As Albert Einstein stated “we cannot solve our problems with the same thinking we used when we created them,” the developers and planners of Arrowhead Springs

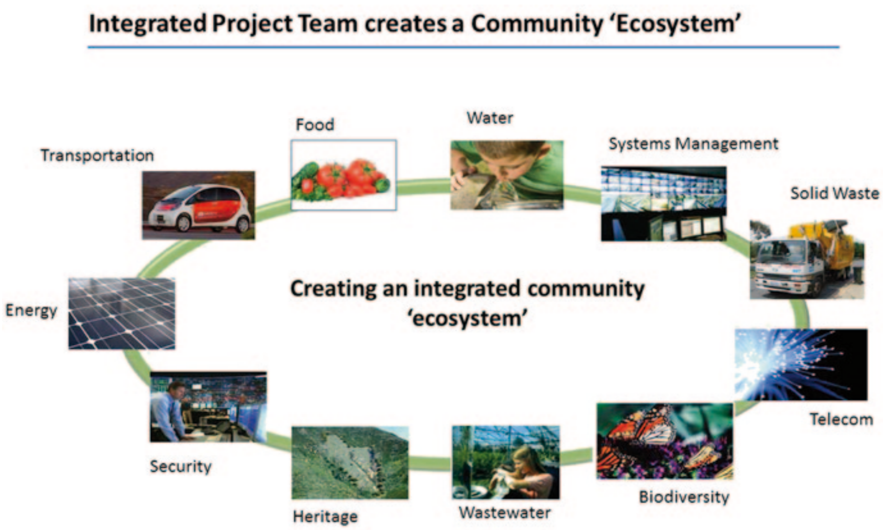

Fig. 12.29 Creating an integrated community "ecosystem." (© Paul Bierman-Lytle 2009)

embraced a different approach when creating the master plan. It begins with understanding the "carrying capacity" or "sustainable capability" that the ecosystem services can provide a human community. Once the ecosystem services have been assessed, based on site research including biology, remote sensing, geology, forestry, biophilia, and a host of other natural and environmental sciences, the development team now has a baseline from which to align human development (real estate development) with ecosystem services. The second phase is to begin assessing the built environment as a complementary "ecosystem service," where all parts are integrated and interdependent (Figs. 12.29, and 12.30).

Starting from the "carrying capacity" of a site's ecosystem services and moving up through design phases is a completely different approach than conventional real estate development (top down) where the planners/architects create a vision of the development, including roads, buildings, and infrastructure *before* they actually know what the ecosystem services can support. The "community as an ecosystem" approach, on the other hand, acknowledges that all human development will benefit from an integrated, interdependent approach. Efficiencies are maximized: energy, water, solid waste, transportation, food production, security, and communications (Figs. 12.31, and 12.32).

At the "macro-level," all systems (utilities, infrastructure, and buildings) are identified and assembled based on what the ecosystem services offer. At the "micro-level," each of these systems, or components, identify appropriate technology or design solutions. Each of these parts is then tested through simulation to determine how effective they fit into the community ecosystem and how they respond or impact ecosystem services (Fig. 12.33).

The final step of the simulation analysis of the proposed technology and design solution options is to run a financial model to ensure that the "ecosystem"

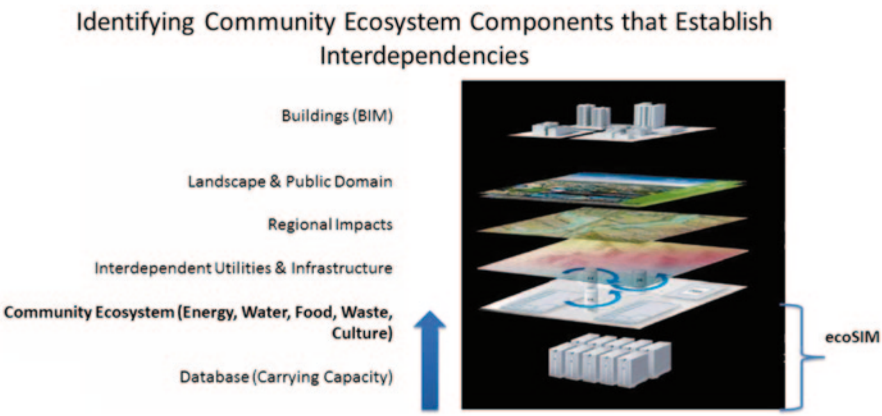

Fig. 12.30 Bottom-up phases of a community ecosystem. (© Paul Bierman-Lytle 2009)

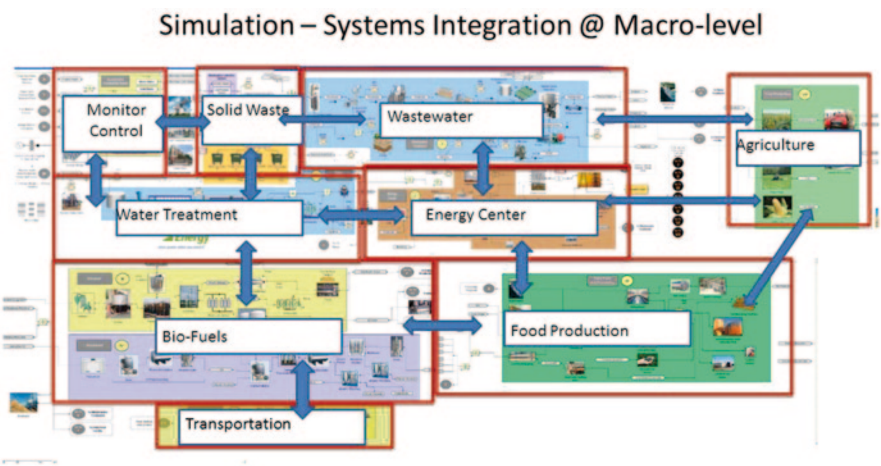

Fig. 12.31 Macro-level simulation of the community infrastructure. (© Paul Bierman-Lytle 2009)

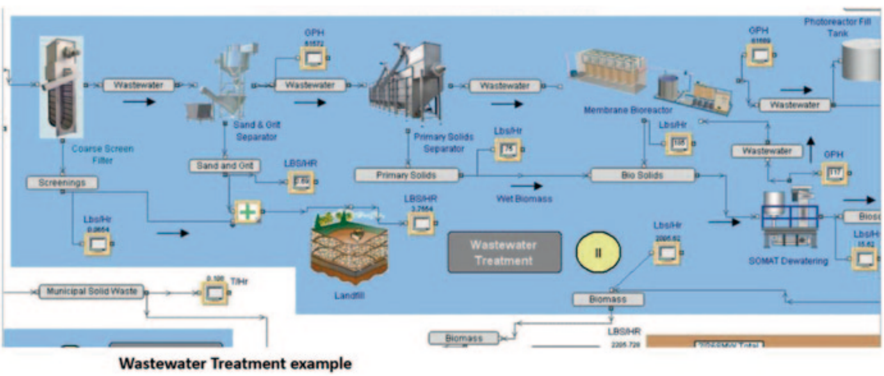

Fig. 12.32 Micro-level simulation of systems. (© Paul Bierman-Lytle, Lee Gary 2009)

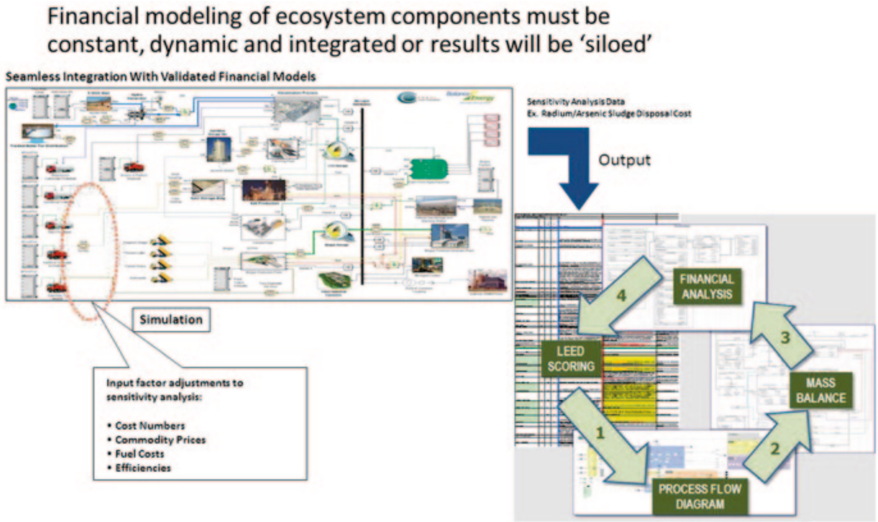

Fig. 12.33 Financial modeling of the community systems. (© Paul Bierman-Lytle, Lee Gary 2009)

Fig. 12.34 Simulation modeling of the community "ecosystem." (© Paul Bierman-Lytle 2009)

components are economically aligned with the financial objectives of the stakeholders. If not, then the process of micro-level analysis repeats itself testing new alternative solutions until a successful financial model is achieved (Fig. 12.34).

Simulation modeling of the entire "community ecosystem" is critical in order to ensure that all ecosystem components are fully integrated and that synergies with the ecosystem services of the natural environment are optimized. Individual buildings, in turn, must "plug-in" effectively to the overall community "ecosystem," otherwise the buildings become a liability and constraint on the system (Figs. 12.35, and 12.36).

Now that the community ecosystem and ecosystem services of the natural environment have been fully integrated, the development can now be effectively monitored each hour, each day of the year. Each component of the community ecosystem and the natural ecosystem services can be reviewed continuously to ensure maximum efficiency and synergy. Adaptations to climate or human activities can be more effectively engaged under this approach (Figs. 12.37, and 12.38).

Fig. 12.35 Simulation of community "plug-in" buildings. (© Paul Bierman-Lytle 2009)

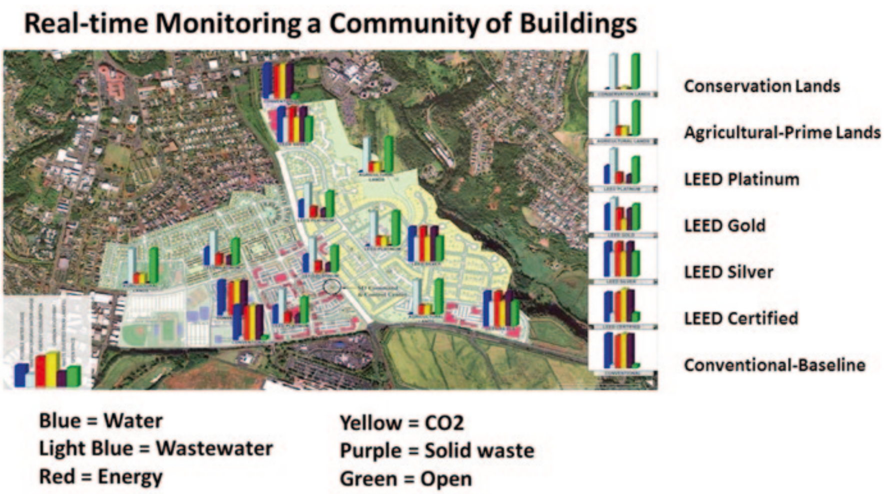

Fig. 12.36 Real-time monitoring of the community. (© Paul Bierman-Lytle 2009)

12.6 Conclusion: What New Paths can We Take? What are Our Options in the Coming Decades?

Human communities must shift from "business as usual" to "mitigation," including economic, cultural, and behavioral shifts. This shift is not an option. Communities must learn to adapt, to change, to modify their lifestyles, habits, and behaviors. If not, the result will be a reduction in quality and quantity of ecosystem services which all human communities depend. More real estate developers must follow examples like Arrowhead Springs, taking the lead to build sustainable communities based on

Fig. 12.37 Central Communications Command and Control Center. (© Paul Bierman-Lytle 2009)

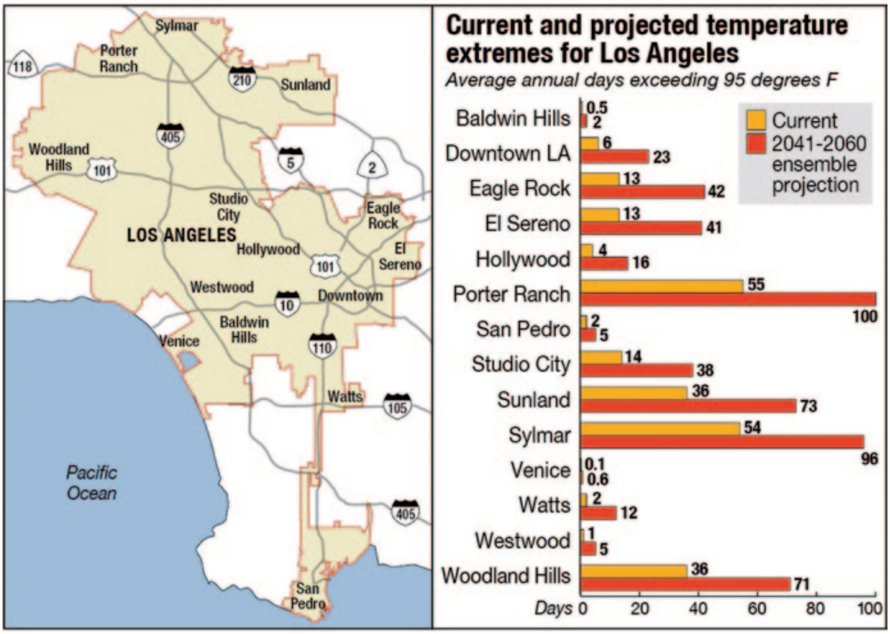

Fig. 12.38 Observed greenhouse gas concentrations in the atmosphere are shown above. The "Climate Change in the Los Angeles Region" project considers climate impacts on both a "business-as-usual" scenario and a "mitigation" scenario. (© C-Change, LA, 2013)

these critical attitude shifts that recognize the full potential of ecosystem services. If approached like Arrowhead Springs, positive engagement of ecosystem services can increase profits by optimization of efficiencies throughout a community's commerce. Healthier, productive, and enjoyable lifestyles will also emerge as human communities acknowledge that ecosystem services are integral to human life.

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Chapter 13
Soil–Plant Interactions in the High-Altitude Ecosystems: A Case Study from Kaz Dağı (Mount Ida), Turkey

Ibrahim Ilker Ozyigit, Zeki Severoglu, Recep Vatansever and Münir Öztürk

13.1 Introduction

Anatolia is one of the richest lands in the world for the natural diversity of its flora and fauna, and has also been a cradle for great civilizations for centuries. The land sustains a unique biological and cultural diversity both in the region as well as on the global scale (Ozturk et al. 1996a, b). It is located at the meeting point of four important floral regions, namely Europe in the Northwest, the Caucasus in the Northeast, Mediterranean in the West and the South, and Mesopotamia in the Southeast (Ozturk et al. 2008, 2010a). Kaz Dağı, known in the history as Mount Ida, is one of the important sites in the country located in the north of Edremit in northwestern Anatolian part within the borders of the states of Çanakkale and Balıkesir. The region has been a center of attraction for the settlers all through the ages because of its fertile soils, wetlands, underground resources, favorable climatic conditions, a premium destination for the ecotourism activities, as a recreation spot, as well as for its floral and faunal richness (Efe et al. 2008, 2011a, b, 2012; Satıl 2009; Uysal 2010; Uysal et al. 2011, 2012). This diversity of the mountain has served and sustained the people around this area for centuries.

In Greek mythology, the region was known as "Mysia" and the people were warriors, originally from Thrace, who settled in Troy around 3000 BC. Later, people from Frig, Mysia, Lydia, Ayonis, and Pers settled in this region (Kelkit et al.

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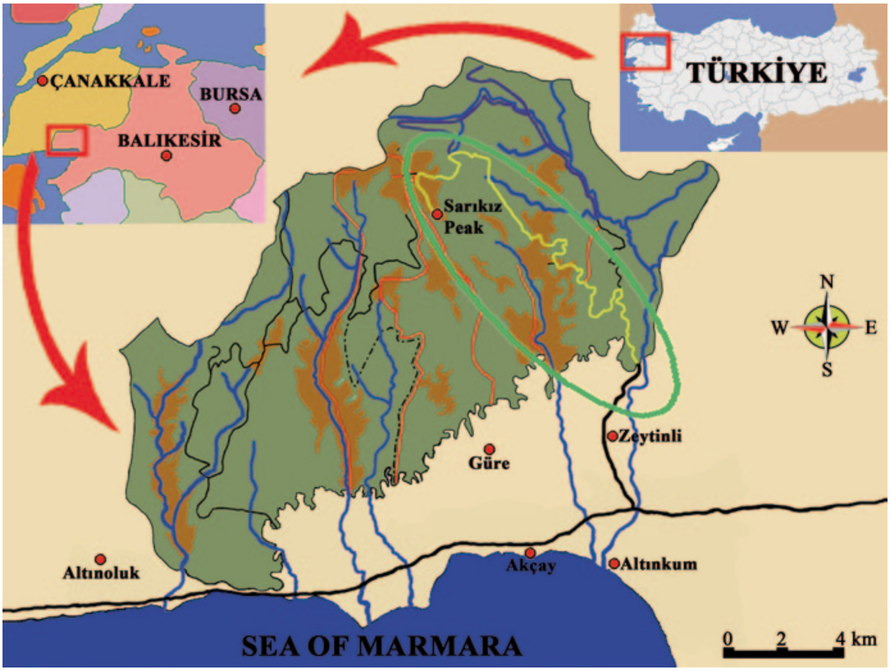

Fig. 13.1 Map showing Kaz Dağı National Park with the study area within the *green circle*

2005). The mountain is known as Mount Ida in the famous epic poem (The Iliad) of Homer (eighth-century BC) (Uysal 2010). According to the legends, the mountain was dedicated to gods and goddess, and all kinds of divine happenings took place on this mountain (Duymaz 2001; Coban 2012).

The mountain is situated at the intersection of two phytogeographically important floral regions; Mediterranean and Euro-Siberian (Uysal 2010), which contributes to its floral richness. The southwestern part of the mountain has been declared as a national park (Fig. 13.1) in 1993, because of its biological diversity, geomorphological features, archeology, cultural resources as well as richness of water resources (Kelkit et al. 2005).

Kaz Dağı has a number of mountain ranges such as Babadağı (1765 m), Karataş (1774 m), Sarıkız (1726 m), Kocatepe (1340 m), Karaçam (1210 m), İnkayası (1180 m), Eybek (1298 m), Öldüren (1060 m), Kocakatrancı (1030 m), and Küçükkatrancı (1015 m) stretching in the east-west direction (Ozel 1999). Zeytinli, Güre, Tuzla, and Gönen wetlands, and Ihlamur and Şahin streams are the main water reservoirs of the mountain (Azatoglu and Azatoglu 2001). These high mountain flowing waters along their way form streams and wetlands; with rich and diverse habitats for numerous plant and animal species; feeding many smaller communities before pouring down into the Aegean and Marmara seas.

13.2 Soils

There are five major types of soils distributed on this mountain (Ozel 1999).

I. *Noncalcareous brown forest soils* are the most common type of soils here, found in almost every aspect and elevation of the mountain. There are A, B, and C horizons with gradual transitions, the B horizon usually at 40–70 cm depth. The A horizon is well formed with porous structure, while the B horizon is not well formed and shows brown or dark-brown granular, or block structure with rounded corners. The organic substances in these soils are generally of acidic character, either separate from the mineral portion or are slightly mixed. The subsoil shows very little or no accumulation of clay. The pH decreases in the lower profiles ($pH < 6$) (Ozel 1999; Uysal et al. 2011).

II. *Brown forest soils* are usually found on the bedrocks containing higher amounts of lime in their structure (Ozturk and Gork 1979). The soil has A, B, and C horizons with gradual transitions, with the B horizon usually at a depth of 50–90 cm. The A horizon is well formed, and shows a porous and granular structure. Organic matter is in the form of mull, thoroughly mixed with mineral substances, the pH is usually basic, rarely neutral, and soil is brown in color. The B horizon shows brown granular or block structure with rounded corners, accumulation of clay is very little but higher than the C horizon. $CaCO_3$ is found at lower layers of this horizon B (Ozel 1999).

III. *Noncalcareous brown soils* also show A, B, and C horizons, the soil is washed, upper parts are brown or light brown in color and easily friable. It shows an acidic character as compared to the subsoil. The B horizon is pale reddish-brown in color. The bedrock is composed of gravel, sand, and clay deposits, especially with the calcareous sandy clay and sandy clay stones exposed to the fragmentation (Ozel 1999; Gregory et al. 2014).

IV. *Red–brown Mediterranean soils* A, B, and C horizons show gradual transition. The A horizon is well formed and contains the organic matter in moderate amounts. It shows red/brown squared blocks or prismatic structures (Verheyen and Rosa 2005). The bedrock is generally composed of hard limestone as well as granite, clay stone, sand stone, various metamorphic rocks, crystalline rocks, flysch, and limestone in the low mountainous regions, and andesitic, dazitic, basaltic rocks, granite clay stone, cemented sand stone conglomerate, marl deposits, various sedimentary rocks, gravel–sandy clay younger sediments, and sandy clay stones in the lower plateaus and plains (Yaalon 1997; Ozel 1999).

V. *Colluvial soils* are the deposit of materials on the weak slopes, carried by the surface flowing waters or streams from short distances. The soil characteristics are more similar to the characters of the surrounding upland soils. According to the degree of slope and rainfall intensity, they contain layers with various particle sizes. These soils have well drainage capacity because of the slope and texture, therefore salt buildup is not observed (Brady and Weil 1996; Ozel 1999; Sumner 1999).

13.3 Vegetation

Forest, shrub, and high mountain are the three main types of vegetation found on Kaz Dağı (Gemici et al. 1998; Uysal 2010).

13.3.1 Forest Vegetation

It is represented by coniferous, deciduous, and mixed forests (Ozturk et al. 1983).

13.3.1.1 Coniferous Forests

Turkish red pine (*Pinus brutia*) forests are typical eastern Mediterranean elements, showing distribution in the western and southern Anatolia as well as on the coast of western Black Sea (Saribas and Ekici 2004; Kurt et al. 2011; Guller et al. 2012). The coverage of this forest vegetation substantially decreased due to anthropogenic factors (Ari 2004; Ari and Kose 2009; Satil 2009). This is especially observed approximately at 250–300 m. The shrub layer is absent or rare under dense forest cover. However, in the areas where the coverage is destroyed, many shrub species in the sub-flora are seen. The following shrub species (0–500 m) are mostly available in the sub-flora on the southern slopes of the mountain: *Anagyris foetida, Arbutus andrachne, A. unedo, Cercis siliquastrum, Cistus creticus, Coridothymus capitatus, Erica arborea, Jasminum fruticans, Laurus nobilis, Lavandula stoechas, Olea europaea, Osyris alba, Phillyrea latifolia, Pistacia terebinthus, Prunus divaricata, P. spinosa, Quercus coccifera, Rhus coriaria,* and *Styrax officinalis* (Uysal 2010; Uysal et al. 2011).

Black pine (*Pinus nigra*) forests are distributed in southern Europe, North Africa, Anatolia, and in Crimea (Scaltsoyiannes 1994; Yucel and Ozturk 2000; Afzal-Rafii and Dodd 2007; Sanchez-Salguero et al. 2013). They begin on the southern slopes at 700–750 m and on the northern slopes of the mountain at about 400 m, and drop down in the Northeast of the mountain to about 270 m. These forests cover the upper part of the mountain and are mostly pure, but in the north and northeastern parts, they are mixed with the fir and broad-leaved beech, oak, hornbeam, and chestnut trees. The following trees and shrubs form mixed communities with the black pine: *Acer platanoides, A. hyrcanum* ssp. *keckianum, Adenocarpus complicatus, Carpinus betulus, Castanea sativa, Chamaecytisus eriocarpus, Crataegus monogyna, Corylus avellana, Cornus mas, Fagus orientalis, Genista lydia, Juniperus foetidissima, Platanus orientalis, Populus tremula, Prunus divaricata, Rubus canescens, Quercus cerris* var. *cerris, Q. frainetto, Q. petraea* ssp. *iberica, Salix pedicellata, Sorbus aucuparia, S. torminalis, Tilia argentea,* and *Vaccinium myrtillus* (Gemici et al. 1998; Ozel 1999; Uysal 2010).

Kaz Dağı fir (*Abies nordmanniana* ssp. *equi-trojani*) is a narrow endemic species (only growing in Kaz Dağı). This endemic species covers an area of 3591.5 ha

(282.5 ha pure fir stands, 3309 ha mixed with *Pinus nigra* ssp. *pallasiana* and *Fagus orientalis*) (Ozel and Simsar 2009). The genetic resource of Kaz Dağı fir is conserved under the national plan for "*In situ* Conservation of Plant Genetic Diversity in Turkey" (Kaya et al. 1997). It is usually occupying the northern slopes of the mountain between 1000 and1400 m, like other fir taxa. Kaz Dağı fir forms mixed communities with following trees and shrubs: *Acer platanoides, A. campestre, Carpinus betulus, Castanea sativa, Crataegus monogyna, Fagus orientalis, P. nigra* ssp. *pallasiana, Populus tremula, Pyrola chlorantha, P. minor, Quercus cerris, Q. petrea* ssp. *iberica, Q. frainetto, Sorbus aucuparia,* and *Sorbus umbellata* (Gemici et al. 1998; Uysal 2010; Uysal et al. 2011).

13.3.1.2 Deciduous Forests

Beech forests (*Fagus orientalis*) have a distribution beginning from the east of Balkans, through Anatolia to Crimea, to the Caucasus and finally reaching northern Iran (Cansaran et al. 2012; Kavgaci et al. 2012). In Turkey, it is found on Amanos Mountains in the South and on Kaz Dağı in the North. They prefer the slopes, which contain more humid and have longer shadowing periods. They are located on the schist bedrock and the soils are noncalcareous brown forest. The following trees and shrubs are associated with the beech species: *Abies nordmanniana* ssp. *equi-trojani, Acer platanoides, Castanea sativa, Carpinus betulus, Corylus avellana, Hedera helix, Pinus nigra* ssp. *pallasiana, Platanus orientalis, Populus tremula, Quercus cerris* var. *cerris, Q. frainetto, Rubus caesius, Rhododendron flavum, Sambucus nigra, Sorbus domestica, Taxus baccata,* and *Tilia argentea* (Uysal 2010; Uysal et al. 2011).

Chestnut (*Castanea sativa*) is mainly distributed in the Black Sea region in Turkey (Ketenoglu et al. 2010). It occupies the elevations between 30 and1500 m and has a scattered distribution in the Aegean and Mediterranean regions. The following species are found as companions in the chestnut forests in Kaz Dağı: *Abies nordmanniana* ssp. *equi-trojani, Alnus glutinosa, Brachypodium sylvaticum, Carpinus betulus, Chamaecytisus hirsutus, Corylus avellana, Euphorbia amygdaloides, Fagus orientalis, Galium verum, Hedera helix, Luzula forsteri, Pinus nigra* ssp. *pallasiana, Pteridium aquilinum, Quercus cerris, Q. frainetto, Q. petraea, Sorbus torminalis, Veronica chamaedrys*, and *Viola odorata* (Ozel 1999).

Hornbeam (*Carpinus betulus*) forests are distributed on the slopes up to 800 m, facing the sea and occupy pebbled areas in northern Anatolia (Gucel et al. 2008). Mostly they are found as mixed communities with following trees and shrubs: *Castanea sativa, Cornus mas, Corylus avellana, Euonymus latifolius, Fagus orientalis, Ilex aquifolium, Malus sylvestris, Quercus cerris,* var. *cerris, Prunus divaricata, Rosa canina, Sorbus domestica, Taxus baccata, Tilia argentea,* and *Ulmus glabra* (Uysal 2010; Kavgaci et al. 2011).

Oak (*Quercus* sp.) forests are located approximately between 300 and 1000 m, and generally prefer sunny and relatively dry southern, eastern, and western slopes. They especially thrive on areas where the black pine forests have been cut or destroyed. Three main species show dominancy here: *Quercus cerris* ssp. *cerris, Q. frainetto,* and *Q. petraea* ssp. *iberica* (Ugurlu et al. 2012; Uysal 2010).

13.3.1.3 Mixed Forests

One of the most important features of Kaz Dağı is that Mediterranean and Black Sea originated species are able to form mixed forests. Black pine–fir, black pine–Turkish pine, black pine–beech, black pine–chestnut, and black pine–oak forests are the main mixed forest types found on Kaz Dağı (Ozel and Simsar 2009).

13.3.2 Shrub Vegetation

The shrub vegetation mainly covers the broad areas between 250 and 600 m elevations in the West and in the Northwest (Ozturk et al. 1983). *Asparagus acutifolius, Amygdalus webbii, Anthyllis hermannii, Cistus creticus, Jasminum fruticans, Juniperus oxycedrus* ssp. *oxycedrus, Olea europaea, Osyris alba, Paliurus spina-christi, Pistacia terebinthus* var. *terebinthus, Prunus divaricata, Quercus infectoria* ssp. *boissieri,* and *Ruscus aculeatus* are the major shrub species distributed on Kaz Dağı (Ozel 1999; Uysal 2010).

13.3.3 High Mountain Vegetation

The species located in 1600 m and over form the high mountain vegetation (Ozturk et al. 1991). *Astragalus idea, Juniperus communis* ssp. *nana, Minuartia juressi* ssp. *asiatica, Nepeta viscida, Narduss stricta,* and *Saxifraga sancta* are the main taxa forming high mountain vegetation in Kaz Dağı (Ozel 1999; Parolly 2004; Nakhutsrishvili 2013).

13.3.4 Flora

Kaz Dağı National Park hosts about 800 plant taxa belonging to approximately 101 families (Uysal et al. 2011). Out of these taxa, 79 are endemic to Turkey and 32 are endemic to Kaz Dağı; 198 are of high ethnobotanical significance (Uysal 2010; Uysal et al. 2012). The endemics and rare species of this mountain have attracted the attention of several botanists (Satıl 2009; Uysal et al. 2011). Most of the endemic species are located at higher altitudes around the Alpine zone (Gungor

2011). Among these endemic taxa, many are of commercial value. Some are important for their secondary metabolites, others have importance for their food values, whereas some are valued for their aromatic and horticultural importance, as well as other purposes (Uysal 2010). The forest areas and the vegetation of this mountain have suffered seriously due to anthropogenic impacts like illegal logging, sulphur dioxide (SO_2) effects from the nearby power plant, acid rains and fires, tourism, festivals, unsustainable agricultural activities, and indiscriminate collection of medicinal plants (Ozturk 1995; Ozel 1999; Satil 2009; Ozel and Simser 2009; Ozturk et al. 2010b, 2011)

13.4 Geomorphometric and Land Cover Relationship

Geomorphometric studies showed that a number of abiotic factors such as altitude, slope, aspect, exposure, latitude, annual average temperature, total annual precipitation, relative topographic humidity, and degree of slope curvature are the primary factors in the formation of rich and diverse flora of Kaz Dağı (Tagil 2006). Especially in mountainous areas, physical environment is an important factor that controls the diversity (Tappeiner et al. 1998; Bolstad et al. 1998; Efe et al. 2011a, b, 2012). In several studies, topography is reported as the main key factor controlling the distribution of vegetation (Barrio et al. 1997). Since topography of a land does not change very frequently, geomorphological formations might be an important indicator in studying ecological classifications and floral productivity of a habitat (Barnes et al. 1982; Host and Pregitzer 1992). In the case of Kaz Dağı, south-facing slopes are exposed to more sunshine than north-facing slopes; therefore, plant communities on the south-facing slopes are subjected to higher transpiration. The areas with higher moisture lead to more sediment movement and erosion as well as causing to form more humid-loving species.

According to Tagil (2006), 8% of the land on Kaz Dağı is below 300 m, 19% between 300 and 600 m, 26% between 900 and 1200 m, 17% between 1200 and 1500 m, and 6% is above 1500 m. The agricultural areas are mainly formed by olive groves, which exist between 0 and 600 m. *Pinus brutia* forests are dominant below 900 m and usually concentrated in the areas below 600 m. However, as the elevation increases, *Quercus* sp. and *Pinus nigra* are observed to form mixed formations with *P. brutia*. *Quercus* sp. are widely distributed between 600–900 and 900–1200 m, mixed with *P. brutia* between 600 and 900 m, and with *P. nigra* between 900 and 1200 m. Thirty-seven percent of *P. nigra* is distributed between 900 and 1200 m and 38% between 1200 and 1500 m. With increasing elevation, *P. nigra* forms mixed formations with *P. nigra–Fagus orientalis–Populus tremula* and *P. nigra–Abies nordmanniana* ssp. *equi-trojani*. The area above 1500 m is made up of stony ground surfaces and covers 82% of the open ground (Table 13.1).

Table 13.1 Elevation and land cover relationship (%) from Tagil 2006

Elevation (m)	Y	Z	A	Cz	CzM	CzCk	M	MCz	MCk	Ck	CkCzM	CkM	CkCz	CkMKs	CkKnKv	CkG
0–300	0	73	1	15	9	0	4	0	0	0	0	1	0	0	0	0
300–600	100	26	2	56	42	60	32	20	6	1	12	12	18	13	0	0
600–900	0	1	1	27	49	40	36	76	42	16	68	44	61	48	0	0
900–1200	0	0	4	2	1	0	25	4	51	37	20	37	21	37	49	0
1200–1500	0	0	9	0	0	0	2	0	1	38	0	4	0	2	51	74

Y settlement areas, *Z* agricultural areas, *A* open ground and stone surfaces, *Cz Pinus brutia, CzM Pinus brutia—Quercus* sp., *M Quercus* sp., *MCz Quercus* sp.—*Pinus brutia, MCk Quercus* sp.—*Pinus nigra, CzCk Pinus brutia—Pinus nigra, Ck Pinus nigra, CkMKs Pinus nigra—Quercus* sp.—*Castanea sativa, CkCzM Pinus nigra—Pinus brutia—Quercus* sp., *CkCz Pinus nigra—Pinus brutia, CkKnKv Pinus nigra—Fagus orientalis—Populus tremula, CkG Pinus nigra–Abies nordmanniana* ssp. *equi-trojani*

13.5 Soil–Plant Interactions on Kaz Dağı (Mount Ida)

Some soil mineral elements (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn) were studied at different altitudes and their potential effects on distribution of plants in high- altitude ecosystems were investigated. In the present study, 500 g of soil samples were collected from five different localities at every 100 m elevation on the road to the national park and along the path leading to Sarıkız Hill inside the park (Fig. 13.1).

The samples were collected from a depth of about 10 cm with a stainless steel shovel and packed in polyethylene bag; oven dried and treated with 9 ml of 65% HNO_3, 3 ml of 37% HCl, and 2 ml of 48% HF respectively; mineralized in microwave oven at 145 °C for 5 min, at 165 °C for 5 min, and at 175 °C for 20 min. After cooling, the samples were filtered by Whatman filters, and added up to 50 ml with ultrapure water in volumetric flasks and stored in Falcon tubes. Mineral element (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn) measurements were done by inductively coupled plasma optical emission spectroscopy (ICP-OES).

Analysis showed that the concentrations of many mineral elements vary at different altitudes (Fig. 13.2). Al concentration was measured an average of 7345 mg/kg at 100 m. This value decreases to an average lowest value of 2345 mg/kg at 600 m, but reaches its highest average value of 9996 mg/kg at 1700 m. The average B concentration is 1.468 mg/kg at 100 m, reaches its highest value with an average of 6.868 mg/kg at 600 m, but steadily decreases to an average of 1.687 mg/kg at 1200 m. After a slight increase (4.003 mg/kg) at 1400 m, it reaches its lowest value of 1.290 mg/kg at 1700 m. The average Ca concentration is 1484 mg/kg at 100 m, reaches a highest average value (3016 mg/kg) at 600 m, but steadily decreases and reaches its lowest average value of 887 mg/kg at 1700 m. Cu has an average value of 6.297 mg/kg at 100 m. At 1000 m, it reaches its highest value with an average of 23.21 mg/kg and over 1000 m it steadily decreases and reaches its lowest average value of 3.547 mg/kg at 1700 m. Fe has an average value of 3320 mg/kg at 100 m, reaches its lowest average value (1378 mg/kg) at 600 m, slightly goes up to 3342 mg/kg at 1000 m. At 1200 m, this value decreases to 1850 mg/kg and reaches its highest value (5434 mg/kg) at 1700 m. K has an average value of 2545 mg/kg at 100 m, shows highest value at 600 m with an average of 3496 mg/kg, steadily decreases reaching its lowest value (1070 mg/kg) at 1400 m, then it shows a slight increase to 1688 mg/kg at 1700 m. Mg has an average value of 1962 mg/kg at 100 m, value increases to 3069 mg/kg at 1000 m, then decreases to 1973 mg/kg at 1200 m, but shows its highest value (3482 mg/kg) at 1700 m with a sharp increase. Mn has an average value of 238 mg/kg at 100 m, reaches its highest average value of 714 mg/kg at 600 m, begins to decrease and reaches its lowest average value (56 mg/kg) at 1700 m. Na has an average value of 397 mg/kg at 100 m, decreases to 181 mg/kg at 600 m and reaches its lowest average value (160 mg/kg) at 1700 m. Ni has an average value of 6.7 mg/kg at 100 m, reaches its highest average value of 26.3 mg/kg at 1000 m. At 1700 m, it sharply decreases to its lowest average value (2.9 mg/kg). Zn has an average value of 5.9 mg/kg at 100 m. This value slightly

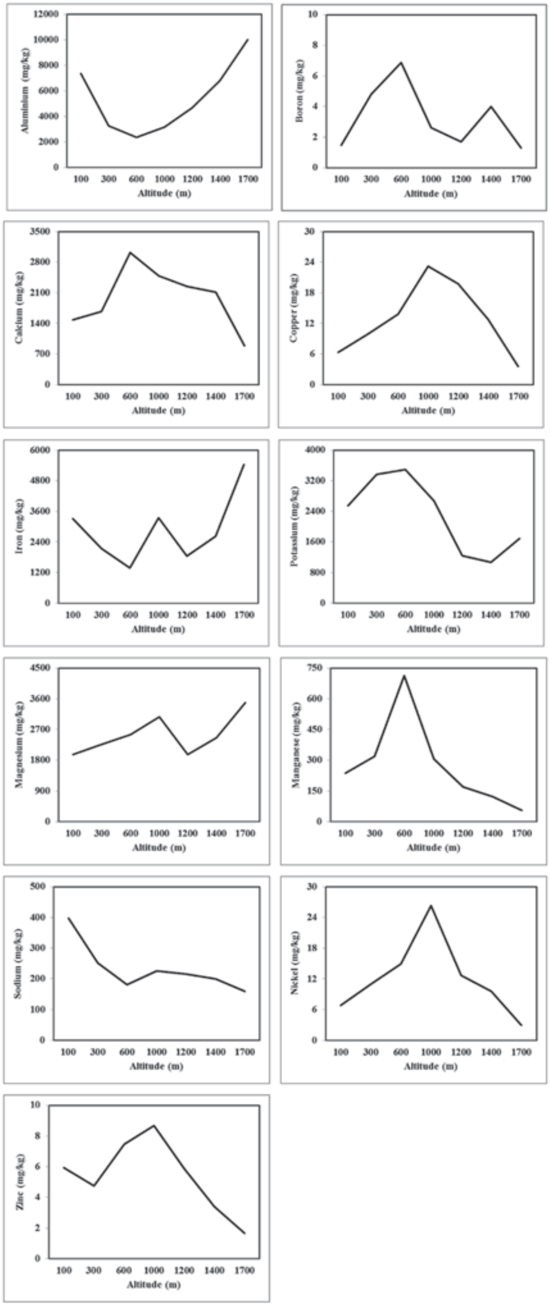

Fig. 13.2 Concentrations of soil mineral elements at different altitudes

Fig. 13.3 Views from different altitudes of Kaz Dağı

decreases up to 300 m, then increases reaching its highest value (8.68 mg/kg) at 1000 m. The average value shows a decrease being inversely proportional to the elevation and reaches its lowest value (1.65 mg/kg) at 1700 m.

Fig. 13.3 (continued)

The mineral element analysis showed that B, Ca, Cu, Mg, Mn, and Ni have lower concentrations at lower elevations; with increasing elevation, the concentrations of these minerals increase to a certain point and then begin to decrease, and reach their lowest values at higher elevations, except for Mg (1600–1700 m). The highest average values for B, Ca, and Mn were measured at 600 m, and for Cu and Ni at 1000 m. Unlike other elements, Al, Fe, and Na represent relatively low values at 600 m. Therefore, 100 m, 600 m, 1000 m, and 1600–1700 m elevations have importance for soil mineralization.

Main plant species observed at different altitudes of the study area follow as (Fig. 13.3):

Between 100 and 200 m, the trees of *Ficus carica* ssp. *carica, Olea europea* var. *europea, Pinus brutia,* and *Punica granatum* are observed. *Adenocarpus compilicatus, Asparagus acutifolius, Cistus creticus, Delphinium* sp., *Micromeria graeca* ssp. *graeca, Pistacia terebinthus, Rhus coriaria, Rubus idaeus, Spartium junceum, Styrax officinalis,* and *Vitex angus-castus* are the other main plant species distributed at this elevation.

Between 200 and 300 m, as the elevation increases, *Pinus brutia* becomes dominant while the density of *Olea europea* var. *europea* decreases. At higher elevations, *Quercus* sp. develop on the degraded *P. brutia* areas. The following species are also observed at this elevation: *Capparis spinosa, Ficus carica* ssp. *carica, Malus sylvestris, Micromeria graeca* ssp. *graeca, Rhus coriaria, Rubus idaeus, Spartium junceum,* and *Styrax officinalis.*

Between 300 and 400 m, *Pinus brutia* is the dominant plant species. *Quercus* sp. has a scattered distribution between *P. brutia* trees, especially on the roadsides. *Digitalis trojana,* which is a Kaz Dağı endemic, is observed at 310 m. Also, in some parts of 390 m *Ficus carica* ssp. *carica* is found.

Between 400 and 500 m, *Pinus brutia* is the dominant species and *Quercus* sp. has a local distribution on some sites of *P. brutia* forests. *Ferulago trachycarpa, Styrax officinalis,* and *Verbascum* sp. are observed on the roadsides.

Between 600 and 700 m, *Echinops* sp., *Micromeria greika, Pinus brutia, Quercus* sp., and *Rhus coriaria* are observed. These species also have an uninterrupted distribution beginning from 100 m up to this elevation.

Between 700 and 800 m, *Pinus nigra* ssp. *pallasiana* first appears at this elevation and becomes dominant at higher elevations. *Pteridium aquilinum* is present under the forest area. *Platanus orientalis, Rosa canina,* and *R. sicula* are locally observed on the roadsides. In addition, up to this elevation, many herbaceous Asteraceae members show continuous distribution.

Between 800 and 900 m, *Pinus nigra* ssp. *pallasiana* is dominant, and *Crataegus monogyna,* and *Platanus orientalis* accompany these forests, especially on the roadsides.

Between 900 and 1000 m, in addition to *Pinus nigra* ssp. *pallasiana, Sideritis trojana* is widely distributed here. *Avena* sp., *Campanula* sp., *Cicer montbretii, Dactylis glomerata* ssp. *hispanica, Dianthus* sp., *Digitalis trojana, Epilobium angustifolium, Euphorbia falcata, E. mrysitenis, Scariola vininea, Scleranthus perennis, Sonchus asper,* and *Verbascum* sp. are the other mainly observed plant species.

Between 1000 and 1100 m, *Epilobium angustifolium* has a wider distribution. *Pinus nigra* ssp. *pallasiana* is the dominant species. Under the forest area, *Pteridium aquilinum* is abundant; beginning from 700 m up to especially 1100 m. *Quercus* sp. is observed to increase at this elevation. *Verbascum* sp. is still observed and *Adenocarpus compilicatus* and *Salvia* species are found abundantly.

Between 1100 and 1200 m, *Pinus nigra* ssp. *pallasiana* is the dominant plant species. *Quercus* species are locally found between *P. nigra* ssp. *pallasiana* trees. In addition, *Heraclium platytaenium* appears as a ruderal.

Between 1200 and 1300 m, in addition to the plant species found between 1000 and 1200 m, *Allium* sp., *Alnus glutinosa, Arabis* sp., *Campanula* sp., *Dianthus arpadianus, Epilobium* sp., *Hypericum kazdaghensis, Juncus* sp., *Scrophularia* sp., *Sideritis trojana, Thymus longicaulis* ssp. *chaubardii* var. *chaubardii,* are observed on the roadsides.

Between 1300 and 1400 m, *Pinus nigra ssp. pallasiana* occurs as a dominant species. *Epilobium* sp., *Pteridium aquilinum,* and *Vaccinium myrtillus* have a wide range of distribution at this elevation.

Between 1400 and 1500 m, *Pinus nigra* ssp. *pallasiana* is the dominant species. Euphorbiaceae and Umbelliferaceae members increase considerably at this elevation. *Achillea frasii* ssp. *trojana* is distributed in a narrow range.

Between 1500 and 1600 m, *Pinus nigra* ssp. *pallasiana* is the dominant species. *Pteridium aquilinum* is very abundant here, whereas *Cirsium* sp., *Inula* sp., and *Quercus* sp. are locally observed.

Between 1500 and 1600 m dwarf *Juniperus* species are widely distributed together with such companions as: *Allium kurtzianum, Anthemis* sp., *Anthyllis vulneraria* ssp. *praepropera, Armeria trojana, Astragalus idaeus, Centaurea odyssey, Chamaecytisus pygmaeus, Cirsium* sp., *Dactylis glomerata* ssp. *hispanica, Dianthus erinaceus, Euprasia* sp., *Galium* sp., *Hypericum kazdaghensis, Lotus corniculatus* var. *alpinus, Paronchia chionae, Pinus nigra* ssp. *pallasiana, Plantago lanceolata, Saxifraga* sp., *Scabiosa* sp., *Teucrium* sp., *Thymus longicaulis* ssp. *chaubardii* var. *chaubardii*, and *Verbascum* sp.

13.6 Climate Change Relations

The scenarios put forward based on the output from four climate models suggest that temperatures are expected to rise by over 4 °C on the inland areas by 2100, and annual precipitation may decrease up to 40 %. Much evidence is now available on a global scale that we "the humans" are influencing our environment to the extent that climate change is going to take place. There will be potentially significant changes at high altitudes. Many valuable ecosystems may vanish because the species may fail to keep up with the shift in climate changes or take to the migration toward safer areas, but such migrations can prove detrimental to these species. Even phonological changes have been reported for many species in particular in the form of early blooming. The temperature warming will push the species to shift to higher elevations where temperatures are favorable for survival. This will in particular endanger the biodiversity at high altitudes. The degraded forests are expected to become vulnerable to erosion if climate change leads to increases in heavy rainstorms. In view of this, particular attention is required to be paid toward the ecosystems at high altitudes before it is too late.

Conclusion

Present study has revealed that up to 600 m altitude in the study area, *Pinus brutia* forests sharply interrupt and replace *Pinus nigra* ssp. *pallasiana* forests. *Juniperus* sp. are widely observed at 1600 m although almost never seen until 1600 m. *P. brutia* and *Quercus* species do not appear at this elevation, but are abundant at lower elevations. Most of Kaz Dağı endemics are observed at higher elevations

(1600–1700 m) (Gungor 2011). The studies done with some narrow endemic species showed that these species, in addition to ecological characteristics of the area, prefer the habitats where mineral element concentrations are either very low or very high (Ozyigit et al. 2013; Altay et al. 2013). If mineral element concentration is very low, some endemic species change their metabolic processes for improvement of accumulation capacity. On the other hand, if mineral element concentration is very high, species develop metabolic modifications where the species either store the elements in vacuoles in order to prevent cellular damage or develop a tendency to wade off these elements. Also, this study showed that concentration of Al, B, Ca, Cu, Fe, Mn and Ni are close to each other between 100-300 m and 1400-1700 m but this is not enough to say a strict relationship between floral distribution and mineral element concentration. If the mineral element distribution became a primary factor for determining floral vegetation of a habitat, then narrow endemic species must have distributed in many areas rather than in particular localities. This also indicates that the plant floral distribution works with many other ecological variables such as temperature, precipitation, slope, wind, sunlight etc. for maximum adaptation but further detailed studies are needed in this connection before climate change scenarios start realizing.

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Chapter 14
Impact of Climatic Change on Flora of High Altitudes in Pakistan

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14.1 Introduction

Everything in the universe is changing with time and nothing is stable except the change. The same is true about the climate. Climate is the mean of meteorological conditions prevailing in a particular area. The rise in global temperature and other associated parameters causes global warming, which can result in the extreme environmental events in future (Ozturk et al. 2010a). The climate keeps on changing on a small scale for a specific area as well as on global level. The changing climate affects every sector of life. These variations are due to certain factors, natural as well as anthropogenic. Human beings intentionally or unintentionally also cause a change in the flora, fauna, precipitation, snow fall, and melting of glaciers, which subsequently and indirectly causes floods, plant and animal extinctions, plant invasions, and disease epidemics in the climatically changed area, and this resultantly affects human behavior, food habits, community structure, trade, transportation, peace and war situation, agriculture, forestry, professions, economies, and even the politics of the affected area. Climate change is a bounty as well as a curse depending on the situation. As a bounty it facilitates us to earn our living. But sometimes it plays havoc in our lives causing catastrophes in the form of natural calamities, whose negative impacts are further aggravated in the underdeveloped and resource-deficient countries by the lack of resources and skills to meet the challenges.

The mountains globally occupy nearly 24% of the land and directly support more than 12% of the world's population (Schild and Sharma 2011). It has been reported that mountains provide services to 20% of the people in the form of water, food, feed, fuel, timber, medicines, and social and spiritual reliefs. The picnic spots and recreation places in Pakistan are only found in the mountains. Apart from these,

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majority of the mountains of high altitude show a rich biodiversity. They are home to a large number of valuable plant and animal taxa, but due to the climate change, these assets are now depleting. Several mountainous regions in Pakistan are still virgin and their biodiversity has not been explored.

The economy of Pakistan is dependent on the climate-sensitive northern belt of the country surrounded by a series of mountains like the Karakoram, the Himalayas, and the Hindu Kush in the form of a semicircle, stretching from west to east. Pakistan's climate has been changing since the last 12 years (1995–2006); 1996 has been ranked among the warmest years in the instrumental record of the global surface temperature since 1850. Widespread changes in extreme temperatures have been observed over the last 50 years. Cold and frost have become less frequent, while hot days, nights, and heat waves have become more frequent (GCISC 2014).

The high-altitude areas in Pakistan; the Hindu Kush Himalayan region (HKH) is one of the largest and most diverse mountain ranges in the world with an area of 4.3 million km^2 of land, with several parallel mountain ranges, such as the Karakoram, the Hengduan, the Himalayas, the Hindu Kush, and the Tibetan Plateau, all comprising diverse landscapes, plateaus, river valleys, and adjoining foothills. These mountains provide water to our rivers, habitats to the wildlife, livelihood to the inhabitants, and beauty to the region (Ning et al. 2013). This region is famous for its rivers, springs, plants and animals, its rich cultures, and aesthetic values. The climate ranges from tropical to high alpine with tropical and subtropical rainforests; temperate broadleaf, deciduous, or mixed forests; temperate coniferous forests; alpine moist and dry scrub, meadows, and desert steppe (Chettri et al. 2008; Sharma et al. 2010). The HKH region is providing shelter to more than 210 million people, and about 1.3 billion people living in the basins of their rivers depend on their products. These mountains vary in altitude and orientations; therefore, extremely diverse forests, grasslands, deserts, and wetlands are found here (Chettri et al. 2008). The region consists of forests (14 %), agriculture land (26 %), rangelands (54 %), water bodies (1 %), and permafrost and glaciers (5 %). In the recent past, the area has faced changes in terms of resource use and developmental activities due to globalization and socioeconomic changes, besides climatic changes with no action plan to counteract the effect of these changes and to understand the significance of these high-altitude ecosystems and their value to the region. There is a dire need to study the climate change effects on the high-altitude ecosystems in order to develop strategies for restoration. Overexploitation of resources, and specially the plants, is severely affecting the lives within and outside the region (Sharma et al. 2010; Aryal et al. 2014). The response of high-altitude ecosystems to climate change is crucial for conservation and developmental planning. Our development may turn into failure in future if "climate-proof" measures are not taken (Stern 2007).

For example, one third of the alpine glacier mass has been lost in the last 120 years until 1970, and almost one half was lost by the year 2000 in about 30 years. Starting from 1970 to 1985, only 1 % of the total mass of glaciers was lost, but from 1985 to 2000, about 20 % of glacier mass was lost. The sudden loss of total glacial mass is most likely a response to climatic change and an abrupt rise in temperature. Based on the data in Intergovernmental Panel on Climate Change (IPCC) report, it

Fig. 14.1 Accelerated glacier melting and temporary lake formation

is expected that the area of glaciers will decline and these may completely disappear by the year 2030 (Hall and Fagre 2003). It is clear that melting of glaciers is not only affecting the amount of flow in our rivers but it is also affecting our flora, particularly the wild plants and weeds, our crops, the agriculture, and other aspects of human life (Fig. 14.1).

The accelerated glacier melting will end up with water scarcity in the future. Other side of the picture will be their impact on the plant diversity of these areas. The native species may become extinct and invasive species may thrive in the new snowless environment. As the invasive species are always best harvesters of water and nutrients, such plants may further increase the severity of the water and nutrient stress for the remaining native vegetation. This may change the whole scenario. At present, we have the problem of invasive weeds like *Parthenium hysterophorus*, *Xanthium strumarium, Lantana camara, Silybum marianum, Conyza canadensis*, *Broussonetia papyrifera*, etc. at high altitudes in Swat, Dir, Chitral, Murree, Haripur, and Mansehra. *Parthenium* infestation started from the base of these mountains along the roadsides and gradually rose up the hills and now it is found everywhere, replacing the native vegetation and mixed populations of *Cannabis sativa, Cynodon dactylon, Malvastrum coromandelianum*, and some other grasses and broad-leaved native plants. *S. marianum* is also highly competitive where the land is fertile with sufficient moisture. *Silybum* has invaded the agricultural fields, water channels, roadsides, and wastelands (Fig. 14.2).

To cope with the future water scarcity for domestic as well as for agricultural purposes, we have to take some precautionary measures to improve water and irrigation system efficiency. The catchment area of most of our rivers is degraded and prone to erosion due to overgrazing, deforestation, disturbances, etc. Therefore, the watersheds should be managed to avoid unnecessary water losses and soil degradation. With each coming day, our water bodies are deteriorating and most of the rivers and streams that we were using in the past for drinking purposes are now unfit for drinking and swimming due to pollution. Increase in human population, industrialization, and the excessive use of agrochemicals has greatly affected the quality of water in our water bodies. The sewage sludge and industrial effluents have

Fig. 14.2 *Silybum marianum* infestation in potato (*left*). *Parthenium hysterophrus* infestation in (*right*)

Fig. 14.3 Availability of water for drinking and domestic use is scarce in several areas of the province

made the aquatic ecosystems favorable for the growth of aquatics like *Eichhornia crassipes, Pistia stratiotes, Typha latifolia*, and *Lemna minor*. Apart from these, the invasion in these aquatic bodies has resulted in a decrease in the number of fauna in these water bodies. The presence of aquatic weeds is a big threat to the future of these water bodies and ultimately to the future of agriculture and our livelihood. The scarcity of drinking water in some areas is a big problem and a big cause of people's health, disputes, and even migration (Fig. 14.3). We also have to take precautionary measures for the future not only to control floods but also to make better use of the flood water and store it for future use. All these could be possible when we take sound steps toward better understanding of the effects of anthropogenic as well as climatic changes on the ecology and biology of weeds and invasive plants. In addition, there should be an excellent monitoring, weather forecasting, and information system as a part of national policy and should strictly and scientifically be adapted and implemented. Harvesting of rainwater can greatly benefit our society so as to be least dependent on the water from other sources as there is no proper strategy for harvesting of rainwater.

Fig. 14.4 Agricultural activities in inaccessible areas at Chitral, Northern Pakistan at the top of hills, destroying the indigenous flora, making the hills prone to further change (*left*). Clearing hill tops for recreational activities (*right*)

The extension of the agriculture to the areas that otherwise were considered protected, like the one (Fig. 14.4) in Chitral, is an important area in northern Pakistan from where many medicinal plants have been reported to have been used for different diseases as folk medicines. Resource-impoverished people used these plants as vegetables as well. Due to better communication facilities and business activities, many people are trying to build their houses at scenic places (Fig. 14.4); construction of houses and hotels on the peak of mountains and farming are becoming luxurious. These situations of changing habitat thereby affect the overall flora and climate of these areas (Ozturk et al. 2008, 2010a, b).

The habitats of many medicinal plants have been disturbed by human activities. Construction of roads in the mountains and construction of houses on the peaks make these mountains accessible for the common people, leading to an early snow melting on the peak, which ultimately affects the flora on the slopes that otherwise are dependent on snow water. Lawari tunnel (10 km long) has made Chitral more accessible for the tourists, imposing a tremendous pressure on wild flora of the area.

14.2 Floods: Causes and Effects

The over melting of the glaciers due to greenhouse gases (global warming) causes formation of temporary dams wherever a space exists across the valley downstream. These temporary dams can be disturbed any time due to weak points in the sides of the dam, by overflow, by earthquakes, and landsliding to cause floods of the dam area below (Kaab et al. 2005). The high mobility of the avalanche may be due to melting at the base causing movement of snow and with continuous supply of water due to frictional melting of ice (Huggel et al. 2005; Eriksson et al. 2009). As earthquakes of low magnitude on Richter scale are common in these areas, in most of the rivers originating from these glaciers in the north of Pakistan, the flood water causes

Fig. 14.5 A lush green valley in northern Pakistan, most of the natural vegetation has been replaced by crops, roads, buildings, and selective forest plantation

havoc in and around these rivers when outburst of these lakes occurs, causing loss of life, agricultural land, flora, fauna, and infrastructure. The effect of floods is more severe and abrupt in the valleys among the mountains as compared to the plains. The recovery and the reclamation after the flood are more difficult and bring an economic burden (Fig. 14.5). The impact of climate change can cause an increase in the outburst of these temporary lakes in the future. These floods can affect local people, but the number of people affected by other types of floods is far more.

Pakistan's agriculture is mainly dependent on the availability of irrigation water in the Indus basin; the food basket of Pakistan, which is based on the water available from the Indus River. Three fourth of the Indus River flow is provided by the glaciers of the Himalayan mountains. The high temperatures due to climate change in the Himalayas will result in rapid melting of the glaciers, which will raise the flow of water initially but in future, it seems that the amount of water will decrease due to decrease in the size of associated glaciers. This will affect the whole agriculture and overall economy. In a study carried out by the Global Change Impact Study Center (GCISC), 14 crops have been assessed for climate change impact (at 0.30 °C per decade). All the selected crops have been found to be suffering due to heat stress. Significant increase in growing degree days (GDD) reduces the growing season length for the crop and thus 8 and 15 % increase in GDD in 2020 and 2050, respectively, is expected. While with an expected 6 % rainfall decrease, the net irrigation water requirements could increase by 29 %, there is much scope for improvement due to global climate change, but research is necessary to address this issue as a challenge (Ozturk et al. 1981; Wallace 2000). The climatic change phenomena at higher altitudes will have an impact on the glaciers, permafrost, and avalanches. All these will have their impact on the water resources, ecosystems, the agriculture, as well as overall system of the mountainous areas like the flora; fauna; mountain infrastructure such as dams, roads, and bridges; and communication systems. The forest ecosystems and forest productivity are at risk due to climate change. How these are threatening the populations requires an assessment to improve relevant knowledge in the region concerning key policy and strategies to improve the adaptive capacities of communities at risk (Jianchu et al. 2007).

Cold and temperate conifers will show a northward shift, pushing against the cold conifer/mixed woodland. The increase in temperature is expected to increase the net primary productivity (NPP) in all biomes during 2020–2050. Under increase or decrease in total precipitation, the NPP of all biomes will not show much increase during these years. The average NPP increase of different biomes, over the base year of 1990, is estimated as 12 % in the year 2020 and 19 % in the year 2040–2050 (calculated) under the climate change scenarios (Stern 2007).

The water demand in the future will increase due to the rising population, not only for domestic supply but also for agriculture. The decline in the water of Indus River will negatively affect the crop yield, as there is no alternative system to supplement this deficiency. This system of irrigation supports the production of more than 500 million t of cereals per year, which is approximately equal to 55 % of the total production of cereals produced in Asia and 25 % of the cereals produced worldwide. This demand will increase by 2050, and we will need about 3000 million t of cereal globally. But due to the ongoing climatic change, the increased glacier melting and associated floods, and later on the reduced water flow in the irrigation system, the production of cereal crops will decrease by 10–30 %. To overcome this problem, we have to develop alternatives for the use of cereals in animal feed such as recycling waste and using fish discards. Mitigating climate change and environmental degradation, investments in green technology, and the implementation of improved irrigations systems, designed to optimize the water irrigation exactly according to plant demand, reducing evaporation and reducing runoffs, could likely increase efficiency in water use (Nellemann and Kaltenborn 2009). Climate change will also change monsoon patterns, and greatly modify the seasons of rains, which will cause floods like the floods of 2008 in Pakistan which destroyed the areas from upper Dir and Swat to Sindh and Karachi about 1500 km away from the origin of flood.

14.3 Use of Glacial Snow in Summer

In the summer season, people from the foothills often go and cut the snow for their use in the hot season. This was called mountain water as compared to the ice prepared in the ice factories. This practice has increased tremendously to the extent of a seasonal business for the people of these areas. The current situation of power shortage in the country and the price hike in electricity bills have further accelerated this practice. This has led to a decrease in the volume of the glaciers to great extent and currently the local people often talk to the visitors of the areas where snow had been there in the near past. Due to low price of the mountain ice, the poor families prefer to buy mountain snow/ice; therefore, this business is extending to other cities of the plain areas.

The snow that disappeared from the various valleys in Dir, Chitral, Kalam, Osho, and Gabral areas of the Upper Swat due to the use of mountain snow in the summer season for cooling of stores and drinking water has had a tremendous effect on the flora of these areas. The small water channels associated with these masses of snow flowing downward had a rich flora and associated fauna but now we find very few plants left behind. On the other hand, the melting of snow during summer was the only source for the wild plants found on the slopes of the mountains. The use of snow is depriving the wild plants from the moisture.

In the Siachen glacier on the Indian side, the Indian army are ruthlessly cutting the snow and burning millions of liters of the fuel over the glacier for clearing the land for construction of buildings and bunkers for security purpose. They do not care for the environment or the flora and fauna. The glaciers are also shrinking due to these activities and this will affect the climate of high altitudes very much in future. This condition is further aggravated by Pak–India political instability with cross-border actions and the issues like Kashmir, Siachen, and Kargil disputes.

14.4 Plant Biodiversity and Forests at High Altitudes

The single biochemical reaction that keeps the biosphere alive (the photosynthesis) is present only in plants which highlights the importance of plants for life on earth. The scientists are working hard on the problem of harvesting the energy of the sun which is directly related to this phenomenon. It is necessary for the flow of energy and carbon through ecosystems. With the exception of a few subterranean organisms, if plants did not exist, life would not exist. However, plants depend on some abiotic factors as well such as sunlight, nutrients, water, and CO_2, and any change in these factors can change the whole biosphere. The diverse ecosystems are sensitive to climate change and other external disturbances as well (Joosten et al. 2012). Climatic change, floods, erratic trend in precipitation, over collection of valuable medicinal plants, various anthropogenic disturbances, earthquakes, steep topography, and turbulent rivers make the HKH region susceptible to external disturbances and natural disasters. Nowadays, most of the high-altitude ecosystems and their flora have degraded, these areas have been desertified, and the steep lands have got eroded (Ozturk et al. 1991, 2008). This phenomenon is further aggravated by climatic change and anthropogenic activities. Most of the steep lands of the mountains where there is no vegetation, frequent landslides, and heavy erosion are seen, which is further increased by deforestation and heavy rains mostly in winter.

The increased food demand due to the population growth is also responsible for the loss of biodiversity. This anthropogenic pressure is increasing with accessibility and popularization of information technology, better transportation, and price hike of the medicinal plants (Ozturk et al. 2010b). Globalization in combination with climatic change has a profound effect on the stability and sustainability of the sensitive ecosystems on the mountainous areas and the livelihoods of local inhabitants. As the physical conditions of the area are prone to change, the anthropogenic activities further complicate the situation in HKH region to handle and cure. Lack of livelihood options, together with modern changes in lifestyle due to information technology, has made the indigenous communities of the landscape extremely

Fig. 14.6 Deforestation for agriculture in progress uphill (*left*). Deforestation caused erosion which subsequently destroyed the plant biodiversity on the hills (*right*)

vulnerable and the flow of indigenous knowledge has virtually stopped due to the engagement of the youth more in TV, Internet, mobile phone, and cable network activities. Biodiversity is likely to face acute threats, so the protection of high-altitude ecosystems is needed to safeguard biodiversity through continued sustenance and long-term sustainability.

Modern agricultural technologies and developments; deforestation for the sake of agriculture, roads, housing schemes, and infrastructure; and urbanization and population expansion are greatly transforming upland and riparian vegetation and wildlife across geographical as well as political boundaries. Human activities have accelerated the process of species extinction, deforestation, desertification, soil degradation, and reduction in the area of wetlands. All these changes are contributing to the climate change on global scale and are of great concern. These will affect the ecosystems other than those at high altitudes too; for example, the agricultural and aquatic ecosystems (Fig. 14.6).

The source of income of the people consists of forestry, collection of wild medicinal plants, agriculture, and animal husbandry. All these are sensitive to climate; a change in temperature or rainfall pattern can affect these sectors significantly. So, preparedness to face the future challenges regarding the global climatic changes will safeguard the country from the harmful impacts of climatic change. In the high altitudes, the climatic conditions are just like those of temperate zone rather than subtropical zone. The vegetation too behaves like temperate zone. This part of the country is rich in the natural resources, particularly the flora, biodiversity, and water resources. The area is a sanctuary for the precious medicinal plants and certain endangered animals which are at the verge of extinction. These medicinal plants are collected from wild and due to the over collection, with no conservation program, certain species are becoming extinct (Fig. 14.7).

The livelihood of most of the people of the area is farming and raring of sheep, goats, and cattle. The herds of sheep and goats browse in the rangelands and adjacent forests. Due to a lack of rangeland management practices and overgrazing, most of the land is bare and prone to erosion due to less absorption capability. The

Fig. 14.7 Overexploitation of forest trees resulting in erosion, desertification, and landslide

floods of 2008 are a result of this, which has caused numerous losses in terms of human lives, health, biodiversity, infrastructure, and buildings (Fig. 14.8).

Rangeland ecosystems stretch across about 2 million km^2 of the HKH region, covering nearly 60 % of the geographical area, and these provide numerous goods and services directly to the local pastoral societies and indirectly to millions of other. The rangelands, forests, and wetlands at high altitudes are affected by climate change and anthropogenic pressures throughout the HKH region leading to reduced supply of goods and services, which not only threatens the livelihoods of local people but also ultimately threatens the sustainability of the whole region. Maintenance of biodiversity and restoration of high-altitude ecosystems is necessary to mitigate climate change. Knowledge on the ecological role of high-altitude ecosystems is needed for conservation and sustainable management planning for their monitoring, evaluation of their services, and management measures to enhance ecosystem resilience and the adaptation. In most areas of Chitral and Gilgit, the native vegetation has been destroyed for agriculture but later on the inhabitants, due to lack of resources and environmental constraints, have left the area uncultivated. The area cannot be recovered easily and often provides favorable conditions for invasive species rather than its native vegetation (Fig. 14.9).

14.5 Armed Conflict in Dir and Swat

In the early 1980s following the Soviet intrusion and occupation of Afghanistan, anti-Soviet groups were created which eventually took the name of Taliban. When Pakistan became an ally of the USA in this intrusion, operations were launched in Swat and Waziristan, resulting in huge losses of life of pashtoons in Khyber Pakhtunkhwa (KPK). It also created political instability, insecurity in the region, suicide attacks became common, large masses of internally displaced persons (IDP) came to the forefront, economy suffered a great loss, investments stopped, and last but not

Fig. 14.8 The flood caused huge losses in terms of crops, animals depended, and infrastructure

Fig. 14.9 Natural vegetation is destroyed once for agriculture. A part is cultivated for wheat while the rest is barren. Such type of habitats cannot be replaced easily once destroyed due to harsh environmental conditions of Chitral

the least the biodiversity and agriculture at the high altitudes in Swat, Dir, and Bajauar suffered great loss. Heavy losses to agriculture and crops were inflicted in the troubled area, two third of standing crops were lost and one third of the wheat was not harvested due to the operations and curfews on daily bases. Forests, fruit trees, and high-stature crops were cut down to have a better monitoring of the militants and the so-called terrorists and their hideouts. Maize and other crops tall enough to hinder the visibility were not allowed to be planted for security reasons and the centuries-old traditional agroecosystem was destroyed. Tobacco, vegetables, rice, orchards, and other valuable crops were harmed and left unharvested, which inflicted huge losses to the farming communities of the area.

The antigovernment activities and the subsequent military operations have severely affected ecosystem functioning as well as the climate and the ecological conditions of a once hospitable environment. This can be divided into two categories: losses due Taliban and losses due to military operations. When Taliban had the hold of Swat and Dir, they took up residence in the thick forests in the mountains and used these forests as their bunkers, hideouts, tunnels, and training camps. They ruthlessly cut down important plant species like *Pinus wallichiana, Picea smithiana, Abies pin-*

Fig. 14.10 Forest fire in Swat

drow, Aesculus indica, Quercus semecarpifolia, Pistacea integerrima, Diospyros lotus, Acer oblongum, and others to make huts and hideouts for themselves. They also utilized the forest trees as a fuel source for cooking and warming their residences as the area was facing severe cold and they also cleared large forest area in just a few months, and utilized the protected forests for themselves and their supporters. The plants provided habitat for hundreds of birds and animal species including rare mammals like jackals, wolves, foxes, monkeys, langur, leopards, pheasants, sparrows, vultures, tits, humming birds, among others. However, the forests were rich in the preferred fuelwood species, so Taliban and their cohorts sold the wood from this area at high prices. Species like *Pinus wallichiana, Abies pindrow,* and *Picea smithiana* are utilized as timber and for furniture production. At one time, a plantation had been carried out in Walli Swat region to preserve biodiversity and ecosystems of this area. *Populus, Ailanthus, Platanus* and *Alnus* trees were planted along roadsides, in colleges, schools, hospitals, and parks, but these were all cut down and destroyed as government property. In Taliban's time, the major destructions were burning and blasting of bridges, schools, colleges, and other government properties, causing many diseases, allergies, tension, anxiety and depressions, etc. Apart from human diseases, many diseases of plants and animals also broke out. The second period of enormous environmental destruction was during military operation, which involved huge bombardment from air to destroy the hideouts of Taliban in forests and hills, resulting in large forest fires for weeks in the forest, destroying large patches of indigenous vegetation (Fig. 14.10). This conflict also affected the honeybees and other pollinators negatively. The gun powder and the bomb blasts caused death of honeybees and other beneficial insects and birds as well. Lack of the pollinators negatively affected the fertilization of various entomophilous plants, reducing their population size and endangering their future generations.

14.6 Social Change

The conflict deeply disturbed the sociopsychology of the people. The violence has had direct psychological impact on the people living in the area. Their constant exposure to violence created many psychological problems, in some cases in the form of serious mental illness. People living in the conflict zone have shown symptoms of acute stress, post-traumatic stress disorders, depression, fear, anxiety, loss of appetite, and sleep disturbance. Similarly, the social issues like poverty and political instability greatly affected the overall biological processes that ultimately affected the ecosystems at the high altitudes of Pakistan.

14.7 Climate Change and Medicinal Plants

Climate change has become increasingly recognized as one of the greatest challenges to plants, causing noticeable effects on the life cycles and distributions of plants (Ozdemir and Ozturk 1996; Ozturk et al. 2010b, 2011). The endemic flora of high altitude is particularly vulnerable to climate change. Changes in snow patterns, ice cover, and temperatures affect their distribution, composition, and survival. The change in temperature and wind affects rainfall. The HKH region is expected to experience the most dramatic climate changes with an increase in temperature of about 5–6 °C. As the medicinal plants are already threatened by overharvest, the additional challenges posed by climate change will push some species to extinction. Extreme weather conditions such as droughts and floods will greatly affect medicinal plants throughout their life cycle. The extremely dry soil conditions resulting from the drought will prevent enough seed production and there is either no germination or less seedling establishment.

The flora at high altitudes in the upper Swat and Dir areas is very diverse containing a high percentage of medicinal plants. The herbalists used to go by themselves to collect plants for medicinal purposes. Later on the local people took the responsibility and the nontechnical persons started collection, and thus medicinal plant collection from wild became an established business without thinking about their conservation and sustainability. We can see heaps of various medicinal plants and plant parts in markets of each city of Swat and Dir particularly Mingora and Timergara. During the war in Afghanistan, millions of Afghan immigrants migrated to Pakistan. Most of them got settled in the Frontier Province in Swat, Dir, Bajauar, and Peshawar. People being business minded, started their own businesses on small scale, and a large number of them collected medicinal plants indiscriminately, which has led to the extinction of some valuable medicinal plants, many are now endangered or at the verge of extinction (Figs. 14.11 and 14.12). These migrants also started selling the wild flowers and fruits to the visitors (Fig. 14.13) without thinking that they are causing extinction of these valuable assets of the nation by cutting and selling the flowers, the reproductive parts of the plants.

14.8 Changes in the Human Diet

Climate change might force changes in diets around the world as certain staple foods will become harder to produce, according to the international reports. However, future shortfalls could be offset by switching to crops which can thrive in those

Fig. 14.11 Over collection of wild fruits. The small school boys harvesting the berries of a wild persimmon *Diospyros* sp.) in Swat, KPK province

altered climates (Ozturk et al. 1981). Important crops like maize and wheat produce less grain at temperatures above 30 °C. Rainfall patterns too are shifting. Water supplies will be strained in some areas, while others will see more floods. Climate change is also altering habitats for pests and diseases. Rice will also suffer. Higher temperatures, salt water encroachment, more flooding, and more droughts are the outcomes of climate change. Some crops in some regions will be able to adapt. For example, by later this century, large parts of Africa will no longer be suitable for growing maize. *Sorghum,* millet, and cassava will become better options. In the light of these findings, it means that changes in people's diets will take place; moreover, warmer temperatures will mean foods will spoil faster. This is something we have not thought a lot about; these kinds of impacts can harm humans.

14.9 Overgrazing and Nonnative Breeds of Animals

The flora of the higher altitude is disturbed due to overgrazing in Swat and Dir areas, particularly due the import of the nonnative sheep species from Australia. These sheep species graze more, are healthy, and can reach areas which were previously not disturbed by the native breeds. They are nonselectively browsing on all or most of the plants and most parts of the same species. For example, the native breeds browse on some wild grasses often take a bit of the plant leaving a considerable size or amount of plant parts for regrowth and regeneration, the new hybrid imported breeds graze slowly over the area clearing the landscape off the most vegetation and leaving nothing for the future regrowth and regeneration.

Grazing can compact soils, increase erosion, and reduce the leafy cover near streams. These effects could be compounded by warming temperatures and changes in rainfall. The hooved animals like horses destroy the rangeland soil and infrastructure when they graze on a rangeland, which are already under additional stress from the climate change. The number of cattle is important for the management and quick recovery of rangelands and affected ecosystems. The overabundance of animals can cause soil erosion, compaction, dust, and water pollution ending up with the loss

Fig. 14.12 A rare medicinal plant Kaveer (*Capparis spinosa*) which is now endangered in its native range Chitral **a** flower, **b** fruits

Fig. 14.13 Local children selling **a** wild flowers and **b** wild fruits to the visitors on the roads

of habitats for fish, birds, and amphibians, and ultimately leading to desertification. Encroachment of woody shrubs at the expense of native grasses and other plants can occur in grazed areas (Figs. 14.14 and 14.15), affecting pollinators, birds, small mammals, and other native wildlife. Overgrazing and trampling degrades soil fertility, increases soil and wind erosion, adds to the sediment accumulation and nutrients in the water bodies, and creates favorable conditions for invasive species to come. Grazing and trampling reduce the capacity of soils to carry on a normal carbon cycle and thus contribute to greenhouse effect and global warming as well.

Suggestions for relieving the overgrazing effects are: proper management of the rangelands is necessary, number of the grazing animal should not exceed the maximum limit regarding the size of the grazing area, land should be fertilized annually, the bare land should be replanted with suitable grasses, large rangelands must be divided into portions that could be kept fallow for the reestablishment of the trampled vegetation, hooved animals should have their specified part of rangeland in order to

Fig. 14.14 Grazing of animals at high-altitude areas in Swat

Fig. 14.15 Overgrazing in extreme drought conditions affects both the rangeland and the herds negatively

decrease the trampling effect, and finally precautionary measures should be adopted against invasive species to avoid their infestation of the grazing land; if there is any infestation, it should be managed as early as possible.

14.10 Invasive Weeds and Flora of High Altitudes

The invasive plants are highly competitive plants once they enter an ecosystem. They take hold of it, occupy the habitat, and let all the native vegetation down by rapid growth, early seeding, more seed production, and allelopathic effects (Ozturk et al. 2007). They cause a decrease in the biodiversity of occupied areas within few years and are difficult to control. The control strategy to be adapted for invasive weeds should be to eradicate them completely, otherwise they will reinfest the area from a small bit of ramet or a few seeds left over there. So the invasive species in the high altitudes in Swat and Dir areas are *Parthenium hysterophorus, Lantana camara, Eucalyptus*, and *Xanthium strumarium*.

Climate change, as well as the interactions between climate change and other environmental disturbances, will turn some native and less-aggressive species into invasive ones like *Pistia stratiotes* which was previously not much aggressive but behaves like an aquatic invasive weed at present, occurring in most of the water bodies of the irrigated plains of the KPK province. Climate change is expected to increase the risk of invasion by weeds from neighboring territories also (Fig. 14.2).

Invasive plant is often a weedy species, usually non-native for a given region, whose introduction results in widespread environmental or species degradation. The invasive plants often show weedy character; good adaptability and response to the global warming, high CO_2 regimes, and elevated humidity are positive factors for these. They thrive better under such conditions where our valuable cereal crops like wheat, oat, and barley are expected to either fail of will become less productive. Evidence shows that rising CO_2 could potentially affect weed populations, crop losses due to weeds, species diversity, forest fires, and failure of the present weed management strategies.

With each coming day, the concentration of CO_2 increases, as is evident from the data published by the GCISC. The CO_2 concentration has increased from 280 (during 1750) to 368 ppm in 2000 (31.4%) and to 379 ppm in 2005 (35.4% increase).

On the other hand, increased CO_2 will affect the closing of stomata which will reduce transpiration and water loss from the plants, thus improving water use efficiency (Ozturk et al. 1981). A doubling of ambient CO_2 concentration causes about 40% decrease in stomatal aperture in both C3 and C4 plants (Ozturk et al. 1981; Morison 1987) which may reduce transpiration by 23–46% (Cure 1986). This might well help plants in environments where moisture currently limits growth, such as in semiarid regions (Gifford 1988).

At high altitudes, temperature is frequently the dominant factor influencing plant growth and seasonality (Turkyilmaz et al. 2013). Plant development starts at a specific temperature and the rate of development increases with increase in temperature to an optimal level above which there is a downward trend (Turkyilmaz et al. 2013). Temperature increase shortens the reproductive phase of determinate crops, decreasing the time during which the canopy exists and thus the period during which it intercepts light and produces biomass. The canopy of indeterminate crops, however, continues to intercept light. An increase in temperature above the base but not exceeding optimum temperatures should therefore generally lead to lower yields in cereals and higher yields of root crops and grassland, though higher temperatures may also lead to higher rates of evaporation and therefore reduced moisture availability that can also be expected to affect yields.

The effects of warming on length of growing season and growing period will vary from region to region and from crop to crop. For wheat in Europe, for example, the growing season is estimated to lengthen by about 10 days/°C and in central Japan by about 8 days/°C (Brouwer 1988; Yoshino et al. 1988).

In general, the conclusion is that increased mean annual temperatures, if limited to 2 or 3 °C, could generally be expected to extend growing seasons in high mid-latitude and high-latitude regions. Increases of more than this could increase evapotranspiration rates to a point where reduced crop-water availability begins to limit the growing season.

Weeds that are well suited to adapt to the impacts of climate change may not only fill gaps left by more vulnerable native plants but also have an even greater effect by altering the composition of ecosystems and their integrity. In fact, climate change may favor certain native plants to such an extent that they then become weeds. Increasing levels of CO_2 may also have an impact on plant growth rates, which may cause changes in weed spread.

Suggestion for invasive weed control is that the spread or introduction of invasive weeds should be prevented, and if they are already introduced into the area, then their infestation should be limited through a comprehensive action plan. This will be only possible if we involve the masses in its execution. The best approach is that of integration of various control methods to make a whole which is economical, feasible, environment friendly, and traditionally acceptable for the people of the area.

14.11 Impact of Increased Accessibility and Transportation

A few years back, most of the areas on the higher altitude were inaccessible and unexplored. The construction of roads and tunnels has made it possible to reach areas previously inaccessible. The recent interest in the herbal medicines and recognizing the worth of the plants have compelled people to take pains to reach the unexplored sites. The construction of roads in the mountains on one hand makes the plants and botanical goods easily available, but on the other hand, destroys the vegetation with the construction process (Fig. 14.16). It also invites the public to come and start erecting buildings on the roadsides and convert a plant sanctuary to a business mall, guest houses, resorts, hotels, health-care centers, etc. These constructions further aggravate the problem and these lead to an increase in the human traffic and human interference in these previously protected areas. Same is true about various developmental projects in the mountainous areas. Construction of roads at high altitudes in the change-sensitive ecosystems endangers most of the indigenous plants (Fig. 14.17). The accessibility also increases tourism and interference of the common masses to the naturally protected areas. The causal visitors in their search of recreation and enjoyment often harm the natural touch of the area either out of ignorance or they do not often care for these assets. On the other hand, climate change reacts as a catalyst that reinforces and accelerates the pace of structural changes in tourism and production-sector tourism will be adversely affected if the tourism did not focus on mitigation strategies (Elsasser and Burki 2002).

14.12 Price Hike of the Wild Fruits and Goods

Nowadays, due to the research regarding the herbal medicines and the side effects associated with the use of allopathic medicines, people's attention is moving towards the plant-based remedies and curing through diet. For example, the wild

Fig. 14.16 Clearing a forest for construction of a hotel/resort for the visitors on Silk Road (Mansehra, KPK) on left. The thick forest trees are visible on the right side of the picture. Site cleared for shops on the roadside on Silk Road in Mansehra (*right*)

Fig. 14.17 These plants are in danger due to cutting of the mountain for road construction and extension and are vulnerable to landslide

tomato *Physalis ixocarpa* can be used instead of tomato as nutritional supplement with a lot of other medicinal benefits, but the use of *P. ixocarpa* has increased in the areas outside its native range and it is now in the endangered position in its native range due to over collection. So the collection of wild medicinal plants has increased manyfold and there is no plan involved for the conservation and fortification of the threatening condition of these plants in the wild. The collectors now face enormous difficulty in collecting and finding wild fruits and medicinal plants any more. This has caused a huge increase in the prices of the wild fruits and plants. This condition might be relieved by sustainable collection methods which can only be done by educating the local community and by cultivating and treating the medicinal plants as minor crops wherever its cultivation is possible.

Conclusions

The ecosystems at higher altitudes are more vulnerable to changes in climate. The rise in temperature due to global warming may cause accelerated glacier melting, resulting in floods and epidemics. This change will fuel species extinction, environmental degradation, and human misery if not scientifically understood and properly worked out in terms of causes, effects, and their mitigation strategies. Overexploitation of resources, armed conflicts, overgrazing, weed invasion, and lack of mitigation and conservation plans when coupled with climate change will further aggravate the situation in creating catastrophical conditions for the existence of human race on earth.

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Chapter 15
Vegetation and Plant Diversity of High-Altitude Mountains in Eastern Karadeniz (Black Sea) Region of Turkey and Climate Change Interactions

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15.1 Introduction

Eastern Karadeniz (Black Sea) is one of the richest regions in terms of biodiversity in Turkey (Gokler and Ozturk 1989; Ozturk et al. 1997, 1998). A total of 3210 vascular plant taxa have been reported as native or naturalized in the region and of these 465 taxa are endemic to Turkey. Fifty of the endemics are in the critically endangered list of the International Union for Conservation of Nature (IUCN), while 67 are in the endangered list. The endemism ratio of the region is very high lying around 14.5% (Ozturk et al. 1997, 1998; Ekim et al. 2000; IUCN 2001; Güner 2012; Fig. 15.1) (Table 15.1). High mountain areas in Artvin, Rize, and Trabzon are the places rich in endemism.

The ecologically important features of the region have attracted the interest of both the biodiversity specialists and international conservation organizations. In 2001, "Conservation International identified the area as Caucasus Biodiversity Hotspot" and listed it among the world's 25 biodiversity hotspots. This hotspot was designated by Conservation International as a conservation priority—meaning that it is a region with exceptional abundance of endemic species and at the same time it is undergoing an exceptional loss of habitat (Ozturk et al. 1997, 1998; Myers et al. 2000; Krever et al. 2001). The region has also been included in the list of the Global 200 Ecoregions and the name of the ecoregion is defined as "Caucasus-Anatolian-Hyrcanian Temperate Forests." Turkey is included in four of these "Global 200 Ecoregions."

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From the phytogeographical point of view, the region lies in the Colchic section of Euxine province of the Euro-Siberian region, one of the three floristic regions in Turkey (Davis 1971). This section represents the farthermost western extension of many species growing in the region. These species include the following trees and shrubs: *Acer cappadocicum, Alnus glutinosa* ssp. *barbata, Betula medwedewii, Daphne glomerata, Diospyros lotus, Picea orientalis, Quercus pontica, Rhamnus imeretina, Rhododendron caucasicum, R. smirnovii, R. ungernii*, and *Sorbus subfusca*.

The herbaceous taxa are: *Chamaesciadium acaule, Draba hispida, Geranium psilostemon, Hypericum bupleuroides, Lathyrus roseus, Lilium ponticum, Lycopodium* spp., *Pachyphragma macrophyllum*, and *Papaver lateritium*.

The alpine flora in the region is closely connected with that of the Caucasus, and shows little floristic connection with the rest of Turkey (Davis 1965). Many studies have been undertaken in the region related to biodiversity (Vural 1996; Ozturk et al. 1997, 1998; Küçük 1998; Terzioğlu 1998; Terzioğlu and Anşin 2001; Varol et al. 2003; Emianağaoğlu and Anşin 2003; Tüfekçioğlu et al. 2004; Terzioğlu 2005; Terzioğlu et al. 2007; Uzun and Terzioğlu 2008). But not much work has been carried out on the influence of climate change on biodiversity of high mountain areas in the region (Tüfekçioğlu et al. 2008). Climate change models predict a significant change in the climate of the eastern and western part of the region (Dalfes et al. 2007). Therefore, it is essential to compile and analyze the existing literature in the region related to biodiversity and climate change effects.

This chapter mainly deals with the areas above 1000 m from sea level which includes forest, the most widespread vegetation type in the region, and the subalpine–alpine ecosystem of the eastern Karadeniz region. The main objective here

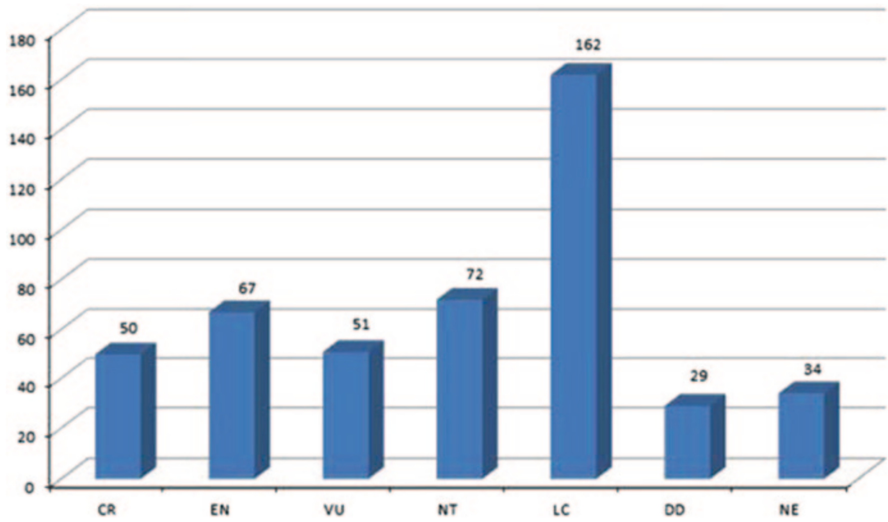

Fig. 15.1 Total number of taxa of the region in IUCN threat categories

Table 15.1 Native threatened taxa of the eastern Karadeniz region

Threat category	Taxa
CR	*Ferula mervynii*
CR	*Archanthemis calcarea* var. *calcarea*
CR	*Archanthemis calcarea* var. *discoidea*
CR	*Centaurea leptophylla*
CR	*Doronicum tobeyi*
CR	*Hieracium amblylepis*
CR	*Hieracium mannagettae*
CR	*Hieracium onosmaceum*
CR	*Hieracium polygonifolium*
CR	*Hieracium rizense*
CR	*Hieracium spodocephalum*
CR	*Hieracium subhastulatum*
CR	*Hieracium subrosulatum*
CR	*Hieracium tersundagense*
CR	*Hieracium tossianum*
CR	*Psephellus yusufeliensis*
CR	*Senecio trapezuntinus*
CR	*Tulipa gumusanica*
CR	*Tanacetum oxystegium*
CR	*Tripleurospermum ziganaense*
CR	*Alyssum nezaketiae*
CR	*Barbarea auriculata var. paludosa*
CR	*Barbarea platycarpa*
CR	*Minuartia buschiana* ssp. *artvinica*
CR	*Silene bayburtensis*
CR	*Colchicum lagotum*
CR	*Colchicum leptanthum*
CR	*Astragalus ansinii*
CR	*Astragalus eliasianus*
CR	*Astragalus olurensis*
CR	*Astragalus trabzonicus*
CR	*Hymenocarpos woronowii*
CR	*Erodium hendrikii*
CR	*Hypericum fissurale*
CR	*Iris nezahatiae*
CR	*Clinopodium serpyllifolium* ssp. *giresunicum*
CR	*Lamium tschorochense*
CR	*Lamium vreemanii*
CR	*Stachys bayburtensis*

Table 15.1 (continued)

Threat category	Taxa
CR	*Gagea tenuissima*
CR	*Acantholimon huetii* var. *huetii*
CR	*Alchemilla akdoganica*
CR	*Alchemilla ayazii*
CR	*Alchemilla ayderensis*
CR	*Alchemilla basakii*
CR	*Alchemilla beyazoglii*
CR	*Alchemilla glabricaulis*
CR	*Alchemilla hayirlioglii*
CR	*Alchemilla ovitensis*
CR	*Crataegus turcicus*
CR	*Viola yuzufelensis*
EN	*Galanthus koenenianus*
EN	*Angelica sylvestris* var. *stenoptera*
EN	*Heracleum sphondylium* ssp. *artvinense*
EN	*Arum rupicola var. rupicola*
EN	*Centaurea drabifolioides*
EN	*Helichrysum artvinense*
EN	*Hieracium diaphanoidiceps*
EN	*Hieracium foliosissimum*
EN	*Hieracium giresunense*
EN	*Hieracium radiatellum*
EN	*Hieracium tamderense*
EN	*Scorzonera mirabilis*
EN	*Senecio ovatifolius*
EN	*Tragopogon fibrosus*
EN	*Turanecio lazicus*
EN	*Onosma circinnata*
EN	*Onosma obtusifolia*
EN	*Paracaryum erysimifolium*
EN	*Symphytum savvalense*
EN	*Symphytum sylvaticum*
EN	*Aethionema grandiflorum* var. *sintenisii*
EN	*Barbarea integrifolia*
EN	*Clypeola raddeana*
EN	*Erysimum leptocarpum*
EN	*Hesperis buschiana*
EN	*Isatis undulate*
EN	*Noccaea sintenisii* ssp. *sintenisii*

Table 15.1 (continued)

Threat category	Taxa
EN	*Campanula choruhensis*
EN	*Campanula grandis* ssp. *rizeensis*
EN	*Campanula troegerae*
EN	*Morina persica* var. *decussatifolia*
EN	*Eremogone scariosa*
EN	*Silene choruhensis*
EN	*Silene manissadjianii*
EN	*Silene scythicina*
EN	*Sempervivum davisii* ssp. *davisii*
EN	*Sempervivum davisii* ssp. *furseorum*
EN	*Blysmus compressus* ssp. *subulifolia*
EN	*Rhodothamnus sessilifolius*
EN	*Cicer reticulatum*
EN	*Onobrychis lasistanica*
EN	*Vicia quadrijuga*
EN	*Erodium absinthoides* ssp. *latifolium*
EN	*Hypericum marginatum*
EN	*Crocus biflorus* ssp. *artvinensis*
EN	*Crocus biflorus* ssp. *fibroannulatus*
EN	*Stachys choruhensis*
EN	*Papaver arachnoideum*
EN	*Veronica gentianoides* ssp. *gentianoides* var. *alpina*
EN	*Acantholimon hypochaerum*
EN	*Elymus longearistatus* ssp. *sintenisii*
EN	*Festuca pontica*
EN	*Reseda armena* var. *scabridula*
EN	*Alchemilla ancerensis*
EN	*Alchemilla cimilensis*
EN	*Alchemilla elevitensis*
EN	*Alchemilla hemsinica*
EN	*Alchemilla ikizdereensis*
EN	*Alchemilla kackarensis*
EN	*Alchemilla trabzonica*
EN	*Potentilla umbrosa* ssp. *decrescens*
EN	*Sorbus caucasica* var. *yaltirikii*
EN	*Asperula virgata*
EN	*Galium tortumense*
EN	*Salix rizeensis*

Table 15.1 (continued)

Threat category	Taxa
EN	*Verbascum decursivum*
EN	*Verbascum trichostylum*
VU	*Bupleurum brachiatum*
VU	*Bupleurum schistosum*
VU	*Pastinaca armena*
VU	*Peucedanum longibracteolatum*
VU	*Seseli andronakii*
VU	*Eminium koenenianum*
VU	*Centaurea aggregata* ssp. *albida*
VU	*Centaurea rhizocalathium*
VU	*Cirsium poluninii*
VU	*Hieracium djimilense*
VU	*Hieracium gentiliforme*
VU	*Inula fragilis*
VU	*Lactuca boissieri*
VU	*Psephellus pecho*
VU	*Psephellus taochius*
VU	*Tephroseris integrifolia* ssp. *karsiana*
VU	*Tripleurospermum rosellum* var. *album*
VU	*Betula browicziana*
VU	*Onosma liparioides*
VU	*Hesperis schischkinii*
VU	*Isatis spectabilis*
VU	*Tchihatchewia isatidea*
VU	*Campanula argentea*
VU	*Gypsophila brachypetala*
VU	*Sedum euxinum*
VU	*Sempervivum staintonii*
VU	*Carex melanorrhyncha*
VU	*Astragalus acmophylloides*
VU	*Astragalus czorochensis*
VU	*Astragalus trachytrichus*
VU	*Onobrychis araxina*
VU	*Crocus aerius*
VU	*Iris histrioides*
VU	*Stachys inanis*
VU	*Papaver lateritium* ssp. *lateritium*
VU	*Linaria genistifolia* ssp. *artvinensis*
VU	*Veronica kopgecidiensis*

Table 15.1 (continued)

Threat category	Taxa
VU	*Elymus lazicus*
VU	*Festuca xenophontis*
VU	*Festuca ziganensis*
VU	*Consolida armeniaca*
VU	*Alchemilla rizensis*
VU	*Alchemilla ziganadagensis*
VU	*Potentilla doddsii*
VU	*Asperula woronowii*
VU	*Galium basalticum*
VU	*Acer cappadocicum* ssp. *divergens*
VU	*Saxifraga artvinensis*
VU	*Verbascum biscutellifolium*
VU	*Verbascum drymophilum*
VU	*Verbascum eriorrhabdon*

CR critically endangered, *EN* endangered, *VU* vulnerable

is to compile and analyze the data related to plant biodiversity and climate change effects in the region.

The native threatened taxa of the eastern Karadeniz region are:

Critical *Ferula mervynii, Archanthemis calcarea* var. *calcarea, A. calcarea* var. *discoidea, Centaurea leptophylla, Doronicum tobeyi, Hieracium amblylepis, H. mannagettae, H. onosmaceum, H. polygonifolium, H. rizense, H. spodocephalum, H. subhastulatum, H. subrosulatum, H. tersundagense, H. tossianum, Psephellus yusufeliensis, Senecio trapezuntinus, Tulipa gumusanica, Tanacetum oxystegium, Tripleurospermum ziganaense, Alyssum nezaketiae, Barbarea auriculata var. paludosa, B. platycarpa, Minuartia buschiana* ssp. *artvinica, Silene bayburtensis, Colchicum lagotum, C. leptanthum, Astragalus ansinii, A. eliasianus, A. olurensis, A. trabzonicus, Hymenocarpos woronowii, Erodium hendrikii, Hypericum fissurale, Iris nezahatiae, Clinopodium serpyllifolium* ssp. *giresunicum, Lamium tschorochense, L. vreemanii, Stachys bayburtensis, Gagea tenuissima, Acantholimon huetii* var. *huetii, Alchemilla akdoganica, A. ayazii, A. ayderensis, A. basakii, A. beyazoglii, A. glabricaulis, A. hayirlioglii, A. ovitensis, Crataegus turcicus,* and *Viola yuzufelensis.*

Endangered *Galanthus koenenianus, Angelica sylvestris* var. *stenoptera, Heracleum sphondylium* ssp. *artvinense, Arum rupicola var. rupicola, Centaurea drabifolioides, Helichrysum artvinense, Hieracium diaphanoidiceps, H. foliosissimum, H. giresunense, H. radiatellum, H. tamderense, Scorzonera mirabilis, Senecio ovatifolius, Tragopogon fibrosus, Turanecio lazicus, Onosma circinnata, O. obtusifolia, Paracaryum erysimifolium, Symphytum savvalense, S. sylvaticum, Aethionema grandiflorum* var. *sintenisii, Barbarea integrifolia, Clypeola raddeana, Erysimum* *leptocarpum, Hesperis buschiana, Isatis undulate, Noccaea sintenisii* ssp. *sintenisii, Campanula choruhensis, C. grandis* ssp. *rizeensis, C. troegerae, Morina persica* var. *decussatifolia, Eremogone scariosa, Silene choruhensis, S. manissadjianii, S. scythicina, Sempervivum davisii* ssp. *davisii, S. davisii* ssp. *furseorum, Blysmus compressus* ssp. *subulifolia, Rhodothamnus sessilifolius, Cicer reticulatum, Onobrychis lasistanica, Vicia quadrijuga, Erodium absinthoides* ssp. *latifolium, Hypericum marginatum, Crocus biflorus* ssp. *artvinensis, C. biflorus* ssp. *fibroannulatus, Stachys choruhensis, Papaver arachnoideum, Veronica gentianoides* ssp. *gentianoides* var. *alpine, Acantholimon hypochaerum, Elymus longearistatus* ssp. *sintenisii, Festuca pontica, Reseda armena* var. *scabridula, Alchemilla ancerensis, A. cimilensis, A. elevitensis, A. hemsinica, A. ikizdereensis, A. kackarensis, A. trabzonica, Potentilla umbrosa* ssp. *decrescens, Sorbus caucasica* var. *yaltirikii, Asperula virgata, Galium tortumense, Salix rizeensis, Verbascum decursivum,* and *V. trichostylum.*

Vulnerable *Bupleurum brachiatum, B. schistosum, Pastinaca armena, Peucedanum longibracteolatum, Seseli andronakii, Eminium koenenianum, Centaurea aggregata* ssp. *albida, C. rhizocalathium, Cirsium poluninii, Hieracium djimilense, H. gentiliforme, Inula fragilis, Lactuca boissieri, Psephellus pecho, P. taochius, Tephroseris integrifolia* ssp. *karsiana, Tripleurospermum rosellum* var. *album, Betula browicziana, Onosma liparioides,, Hesperis schischkinii, Isatis spectabilis, Tchihatchewia isatidea, Campanula argentea, Gypsophila brachypetala, Sedum euxinum, Sempervivum staintonii, Carex melanorrhyncha, Astragalus acmophylloides, A. czorochensis, A. trachytrichus, Onobrychis araxina, Crocus aerius, Iris histrioides, Stachys inanis, Papaver lateritium* ssp. *lateritium, Linaria genistifolia* ssp. *artvinensis, Veronica kopgecidiensis, Elymus lazicus, Festuca xenophontis, F. ziganensis, Consolida armeniaca, Alchemilla rizensis, A. ziganadagensis, Potentilla doddsii, Asperula woronowii, Galium basalticum, Acer cappadocicum* ssp. *divergens, Saxifraga artvinensis, Verbascum biscutellifolium, V. drymophilum*, and *V. eriorrhabdon.*

15.2 High Mountainous Vegetation of Eastern Karadeniz Region

The high mountainous part of the region is mainly covered by forest and subalpine–alpine vegetation types. Plant associations of forest vegetation of the region belong to the Querco-Fagetea class, which is represented in the region with two endemic orders, namely Rhododendro-Fagetalia orientalis and Pino-Piceetalia orientalis (Fig. 15.2). Alnion barbatae and Castaneo-Carpinion alliances of Rhododendro-Fagetalia orientalis are represented widely in the region (Düzenli 1979; Güner et al. 1987; Küçük 1998; Terzioğlu 1998). This class is mainly characterized throughout northern Anatolia by *Aruncus vulgaris, Athyrium filix-foemina, Blechnum spicant, Carex ornithopoda* ssp. *ornithopoda, Carex sylvatica, Circaea lutetiana, Listera*

Fig. 15.2 Different forest types from eastern Karadeniz region of Turkey

ovate, Viburnum opulus, Millium effusum, Mycelis muralis, Myosotis sylvatica, Polystichum filix-mas, Sanicula europaea, Veronica officinalis, Stellaria holostea, and *Galeobdolon luteum* (Akman 1995).

Characteristic species of Rhododendro-Fagetalia orientalis are *Acer cappadocicum, Acer trautvetteri, Achillea biserrata, Daphne pontica, Epimedium pubigerum, Fagus orientalis, Rhododendron ponticum, R. luteum, Ruscus hypoglossum, Salvia forskahlei, Scilla bitynica, Festuca montana, Hedera colchica, Hypericum calycinum, Ilex colchica, Lapsana communis* ssp. *alpina, Quercus petraea* ssp. *iberica, Smilax excelsa, Sophora jaubertii, Tilia rubra* ssp. *caucasica, Trachystemon orientalis*, and *Vaccinium arctostaphylos*. This order is represented by three alliances: *Crataego-Fagion*, *Castaneo-Carpinion*, and *Alnion barbatae* (Akman 1995).

Characteristic species of *Pino-Piceetalia orientalis* are *Abies nordmanniana ssp. nordmanniana, Cardamine impatiens ssp. pectinata, Cyclamen coum ssp. caucasica, Dryopteris liliana, Dryopteris dilatata, Viburnum orientale, Paris incompleta, Picea orientalis, Pinus sylvestris, Sedum stoloniferum, and Ranunculus cappadocicus*. This order is represented by two alliances: *Veronico-Fagion* and *Geranio-Pinion* (Akman 1995).

Alpine and subalpine vegetation types are represented by one class, two orders, five alliances, and eight associations (Vural 1996). Alchemillo retinervis-Sibbaldietea parviflorae is characterized by *Alchemilla caucasica, A. pseudocartalinica, A. retinervis, Cerastium purpurascens, Crocus vallicola, Euphraisia sevanensis, Gentiana septemfida, Minuartia aizoides, Phleum alpinum, Polygala alpestris, Sedum annuum, Tripleurospermum oreades, Trifolium ambiguum, Veronica gentianoides, Anthoxanthum odoratum* ssp. *alpinum, Carex caucasica, Carex atrata* ssp. *atrata, Carex atrata* ssp. *aterrima, Gnaphalium stewardtii, Luzula pseudosudetica, Minuartia recurva* ssp. *oreina, Pilosella hoppeana* ssp. *testimonialis, Polygonum bistorta* ssp. *Carneum, Sibbaldia parviflora, Taraxacum crepidiforme*, ssp. *crepidiforme, Ranunculus brachylobus* ssp. *brachylobus, Viola altaica* ssp. *oreades*, and *Gentianella caucasae*. The class is represented in the region by two orders: Alchemillo retinervis-Sibbaldietalia parviflorae and Swertio ibericae-Nardetalia strictae (Fig. 15.3). The class is distributed over NE Anatolia between 2000 and 3100 m and is rich in herbaceous and very attractive flowering plant taxa.

Fig. 15.3 Views from alpine areas of the eastern Karadeniz region of Turkey

The characteristics are: *Alchemilla caucasica, A. pseudocartalinica, A. retinervis, Nathoxanthum odoratum* ssp. *alpinum, Carex caucasica, C.atrata* ssp. *atrata, C. atrata* ssp. *aterrima, Cerastium purpurascens, Crocus vallicola, Euphrasia sevanensis, Gentiana septemfida, Gentianella caucasae, Gnaphalium stewartii, Luzula pseudosudetica, Minuartia aizoides, M. recurva* ssp. *oreina, Phleum alpinum, Pilosella hoppeana* ssp. *testimonialis, Polygala alpestris, Polygonum bistorta* ssp. *carneum, Ranunculus brachylobus* ssp. *brachylobus, Sedum annuum, Sibbaldia parviflora, Taraxacum crepidiforme* ssp. *crepidiforme, Tripleurospermum oreades, Trifolium ambiguum, Veronica gentianoides*, and *Viola altaica* ssp. *oreades* (Vural 1996).

Characteristic species of Alchemillo retinervis-Sibbaldietalia parviflorae are *Achillea latiloba, Androsace albana, A. intermedia, Astragalus oreades, Carex brevicollis, Campanula aucheri, C. collina, C.stevenii* ssp. *beauverdiana, C. stevenii* ssp. *stevenii, C.tridentata, Centaurea nigrifimbria, Cerastium dahuricum, Chaerophyllum astrantiae, Daphne glomerata, Draba hispida, Erigeron caucasicus* ssp. *caucasicus, E. caucasicus* ssp. *venustus, Euphrasia petiolaris, Festuca chalcophaea* ssp. *chalcophaea, Geranium cinereum* ssp. *lazicum var. lazicum, G. cinereum* ssp. *lazicum* var. *ponticum, G. platypetalum, Gypsophila silenoides, Hedysarum hedisaroides, Minuartia imbricata, Pedicularis nordmanniana, Poa longifolia, Potentilla ruphrectii, Rumex tuberosus* ssp. *horizontalis, Sedum spurium, S. tenellum, Silene saxatilis, Stachys balansae* ssp. *balansae, Stachys macrantha,* and *Thymus praecox* ssp. *grossheimii*.

The order is represented by four alliances: *Agrostio lazicae-Sibbaldion parviflorae*, *Lilio pontica-Anemonion narcissiflorae*, *Centaureo appendicigerae-Senecion taraxacifolii*, and *Vaccinio myrtilli-Rhododendrion caucasici* (Vural 1996).

Characteristic species of *Swertio ibericae-Nardetalia strictae* are *Alchemilla mollis, Caltha polypetala, Cardamine uliginosa, Carex nigra* ssp. *dacica, C. nigra* ssp. *nigra, C. pallescens* var. *chalcodeta, C.pyrenaica, Geum coccineum, Nardus stricta, Pinguicula balcanica* ssp. *pontica, Primula auriculata*, and *Trifolium spadiceum*. This order is represented by one alliance Swertio ibericae-Nardion strictae (Vural 1996). All plant associations given below are distributed at altitudes over 1000 m above sea level (asl).

15.2.1 Deciduous Forests

15.2.1.1 Castanea sativa–Fagus orientalis

This association consists mainly of three layers—trees, shrubs, and herbs—and is distributed over the Karadeniz region. Characteristic species are *Castanea sativa, Fagus orientalis, Hedera colchica, Hypericum androsaemum, Trachystemon orientalis, Taxus baccata*, and *Ruscus colchicus*. Rhododendro-Fagetalia orientalis is characterized by 15 taxa, mainly *Rhododendron ponticum* and *Vaccinium arctostaphylos*.

Alnion barbatae is dominated by *Alnus glutinosa* ssp. *barbata* and *Thelypteris limbosperma,* and Castaneo-Carpinion is dominated by *Rubus platyphyllos*. These are characterized by more than 10 taxa.

Fagetalia sylvaticae, Pino-Piceetalia orientalis, and Quercetea pubecentis are also represented.

Querco-Fagetea is represented by 14 taxa mainly *Blechnum spicant* and *Corylus avellana* ssp. *pontica*. Although this mixed forest is distributed at an altitude lower than 1000 m, these species are seen up to 1500 m in forests with close canopy (Vural 1996).

15.2.1.2 Fagus orientalis–Rubus caucasicus

This association is distributed at Tiryal mountain (Artvin province) between 800 and 1550 m asl (Düzenli 1979). The forest vegetation has been dominated almost by oriental beech. Along the river, *Alnus glutinosa* ssp. *barbata* taxon is distributed as the dominant species.

This association consists mainly of three layers: the trees, shrubs, and herbs. Characteristic species are *Fagus orientalis, Rubus caucasicus, Brunnera macrophylla, Rhododendron ponticum, R. luteum, Viburnum orientale*, *Ilex colchica*, and *Neottia nidus-avis*.

Rhododendro-Fagetalia orientalis is characterized by nine taxa mainly by *Rhododendron ponticum, Rh. luteum, Ilex colchica*, and *Rubus platyphyllos*.

Alnion barbatae is mainly characterized by *Alnus glutinosa* ssp. *barbata, Thelypteris limbosperma*, and *Circaea lutetiana*.

Fagetalia sylvaticae, Pino-Piceetalia orientalis, and Quercetea pubecentis are also represented (Duzenli 1979).

15.2.2 Mixed Deciduous and Conifer Forests

15.2.2.1 Fagus orientalis–Picea orientalis

This association is usually dominant on the north-, east-, and south-facing slopes, at altitudes up to 1500 m asl and consist mainly of three layers such as trees, shrubs, and herbs. It has been recorded firstly from the Rize province. The total coverage of the tree layer lies between 85 and 95%, as the same coverage of shrub layer. It is a member of the Castaneo-Carpinion association. Characteristic and differential species are: *Castanea sativa, Fagus orientalis, Hedera colchica, Hypericum androsaemum, Trachystemon orientalis, Taxus baccata,* and *Ruscus colchicus*. Rhododendro-Fagetalia orientalis is strongly represented in the association (Quezel et al. 1980).

15.2.3 Pure Forests

15.2.3.1 Picea orientalis–Sedum stoloniferum

This association is usually dominant on the north-, west-, and northwest-facing slopes and at altitudes between 1100 and 1800 m asl, and consists mainly of tree, shrub, and herb layers, recorded from Rize and Trabzon provinces. The total coverage of the tree layer is between 85 and 95%. Veronico-Fagion and Geranio-Pinion are represented. Characteristic and differential species are: *Picea orientalis, Sedum stoloniferum, Solidago virgaurea, Dryopteris expansa, Aruncus vulgaris, Digitalis ferruginea* ssp. *schiskhinii, Viola sieheana, Goodyera repens, Lonicera caucasica* ssp. *orientalis, Cephelanthera longifolia, Dryopteris borreri, Stellaria nemorum, Crepis paludosa, Symphytum asperum, S. longipetiolatum, Psoralea acaulis, Argyrolobium biebersteinii,* and *Aster caucasicus*. Pino-Piceetalia orientalis are strongly represented in the association. This association has two subassociations as *piceetosum orientalis* and *fagetosum orientalis* (Vural 1996; Terzioğlu 1998).

15.2.3.2 Picea orientalis–Paris incompleta

Here too, we find tree, shrub, and herb layers, but the moss layer is very rich including nine species. It is rich in characteristic species like: *Picea orientalis, Paris incompleta, Arenaria rotundifolia, Euphorbia oblongifolia, Cyclamen parviflorum, Ranunculus buhsei,* and *Oxalis acetosella.* These forests have very dense canopy and Rhododendro-Fagetalia orientalis has not been represented in it contrary to expectation. This pure coniferous forest is distributed up to 1900 m asl with the close canopy (Duzenli 1979).

15.2.3.3 Picea orientalis–Telekia speciosa

The association is distributed over the north slope of Zigana Mountains (around Trabzon and Gümüşhane province) and the canopy cover is about 80%, consisting mainly of trees, shrubs, and herbs. The association is distributed between 1600 and 1800 m asl. According to Akman (1995), the characteristic and differential species are very clear to distinguish this association, which are: *Picea orientalis, Gentiana asclepiadea, Chaerophyllum macrospermum, Impatiens noli-tangere, Telekia speciosa, Valeriana alliarifolia, Alnus glutinosa* ssp. *barbata, Symphytum asperum,* *Thelypteris limbosperma, Geranium sylvaticum, Ranunculus buschei, Cardamine raphanifolia, Aruncus vulgaris, Geranium sintenisii, Thelypteris dryopteris, Cirsium pseudopersonata, Rhynchocorys stricta, Campanula latifolia, Senecio lazicus,* and *Trollius ranunculinus*. In this association, Pino-Piceetalia orientalis is strongly represented and Rhododendro-Fagetalia orientalis is weakly represented. Nearly all characteristic species of Geranio-Pinion can be seen in this association (Quezel et al. 1980).

15.2.3.4 Picea orientalis–Doronicum macrolepis

The tree, shrub, and herb layers of this association are distributed in a restricted area around Trabzon along the Harşit River, but the plant species diversity is poor. Two of the four characteristic and differential species are endemics: *Senecio trapezuntinus* and *Doronicum macrolepis*. In addition to these, *Picea orientalis* and *Abies nordmanniana* ssp. *nordmanniana* are also found here. The floristic composition of the association includes the characteristic species of the alliance Buxo-Staphyllion. It has been pointed out that explanation of the exact phytosociological position of this association is difficult (Quezel et al. 1980).

15.2.3.5 Pinus sylvestris–Vaccinium myrtillus

This association is usually dominant on the north-, west-, and northeast-facing slopes and at altitudes between 1700 and 2100 m asl. The total coverage of the tree layer varies between 60 and 80 %.

Pino-Piceetalia orientalis and Veronica-Fagion are strongly represented in the association. It is closely related to association *Pinus sylvestris–Daphne glomerata* but this association is the member of Geranio-Pinion. Though some floristic differences are evident, the association is distributed in both Trabzon and Giresun. Characteristic and differential species are *Pinus sylvestris, Vaccinium myrtillus*, *Pyrola rotundifolia, Scilla monanthos, Monoses uniflora, Luzula campestris,* and *Orthilia secunda* (Quezel et al. 1980).

15.2.3.6 Pinus sylvestris–Lilium ciliatum

This association too exhibits tree, shrub, and herb layers and is related to the association *Picea orientalis–Telekia speciosa*, but differs from it in terms of dominant species (*Pinus sylvestris*) and lack of *Picea orientalis*; less hygrophytic species are seen in this association. The association is distributed between 1500 and 1700 m asl. The association includes the characteristic species of the Pino-Piceetalia orientalis order and the Geranio-Pinion alliance. *Carpinus orientalis*, the member of Querco-Carpinetalia, is dominant at lower altitudes of this association. It is distributed in a restricted area around Zigana Mountains (Trabzon and Gümüşhane provinces). Characteristic and differential species are *Pinus sylvestris, Lilium ciliatum,* *Ranunculus brachylobus, Viburnum lantana, Vcia freyneana, Primula vulgaris, Tripleurospermum monticolm,* and *Melampyrum arvense* (Quezel et al. 1980).

15.2.3.7 Pinus sylvestris–Astragalus adzharicus

This association is distributed in Tiryal Mountain (Artvin province). It exhibits tree, shrub, and herb layers, and the total coverage of the tree layer varies between 40 and 70 %. The association consists of many local endemic characteristic and differential taxa. Pino-Piceetalia orientalis is clearly represented. Distribution of *Pinus sylvestris* forest starts from 120 to 2000 m asl in Tiryal Mountain. However, *Pinus sylvestris* forest at the lower altitudes of the same watershed belongs to Rhododednro-Fagetalia order. Characteristic and differential species are *Pinus sylvestris, Astragalus adzharicus, Seseli andronakii, Uechtritzia armena,* and *Ferulago setifolia* (Duzenli 1979).

15.2.3.8 Pinus sylvestris–Daphne glomerata

This association resembles the associations cited above, but differs from them physionomically. *Abies nordmanniana* ssp. *nordmanniana* is found in this association. The total coverage of the tree layer lies between 60 and 80 %. The shrub layer is very dense and dominated mainly by *Rhdodendron ponticum* and *R. luteum*. The association is distributed between 1700 and 2100 m asl and reaches up to the subalpine zone. This association includes the characteristic species of the order Pino-Piceetalia orientalis and the Geranio-Pinion alliance (Quezel et al. 1980).

15.2.3.9 Pinus sylvestris–Juniperus communis

This association too consists mainly tree, shrub, and herb layers. The total coverage of the tree layer lies between 60 and 80 %. Characteristic and differential species of the association are *Pinus sylvestris, Juniperus communis* ssp. *saxatilis, Tripleurospermum melanolepis, Phleum exaratum* ssp. *exaratum, Daphne glomerata, Centaurea triumfettii, Echium russicum, Campanula sibirica* ssp. *hohenackeri*, and *Pilosella x auriculoides*. The association is distributed between 1900 and 2000 m asl on the south-facing slopes. In this association, the components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well presented (Eminağaoğlu et al. 2007).

15.2.3.10 Betula litwinowii–Anemone narcissiflora ssp. narcissiflora

This association occupies the subalpine zone of the Solaklı watershed (Trabzon province) and is distributed between 2030 and 2300 m asl. It exhibits mainly two vertical layers, and the total coverage of the shrub layer is about 85 %. However, the cover of tree layer is less than 1 %. This association is very rich in plant species diversity with more than 100 taxa and includes many attractive flowering species. It is a member of the Lilio pontici-Anemonion narcissiflorae alliance and the Alchemillo retinervis-Sibbaldietalia parviflorae order. Characteristic and differential species are *Betula litwinowii, Anemone narcissiflora* ssp. *narcissiflora, Aconitum nasutum, Lilium corniolicum* ssp. *ponticum* var. *ponticum, Helianthemum nummularium* ssp. *tomentosum,* and *Euphorbia squamosal* (Terzioğlu 1998).

15.2.4 Mixed Forests

15.2.4.1 Picea orientalis–Quercus petraea ssp. iberica

This association also consists mainly of tree, shrub, and herb layers. The total coverage of the tree layer is between 65 and 90 %. Characteristic and differential species of the association are *Picea orientalis* and *Quercus petraea* ssp. *iberica.* The association is distributed between 1100 and 1500 m asl on the south-, west-, and southwest-facing slopes. In this association, the components of the Carpino-Acerion and Querco-Carpinetalia orientalis order are well presented. It has two subassociations as *fraxinetosum angustifoliae* and *cratagetosum microphillae* (Eminağaoğlu et al. 2007).

15.2.4.2 Picea orientalis–Pinus sylvestris

This association also has tree, shrub, and herb layers. The total coverage of the tree layer is between 85 and 100 %. Characteristic and differential species of the association are *Pinus sylvestris, Picea orientalis,* and *Limodorum abortivum.* The association is distributed at about 1400–1600 m asl on the south-, west-, and southwest-facing slopes. The components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well represented here (Eminağaoğlu et al. 2007).

15.2.4.3 Picea orientalis–Abies nordmanniana ssp. nordmanniana

The association again consists mainly of three layers as above. The total coverage of the tree layer is between 80 and 100 %. Characteristic and differential species of the association are *Picea orientalis, Abies nordmanniana* ssp. *nordmanniana, Vicia crocea, Solidago virgaurea* ssp. *virgaurea, Symphytum longipetiolatum, Crepis paludosa, Digitalis ferruginea* ssp. *schischkinii,* and *Symphytum asperum.* The association flourishes between 1650 and 1750 m asl on the east-, southeast-, and north-facing slopes. The components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well presented in this association (Eminağaoğlu et al. 2007).

15.2.4.4 Pinus sylvestris–Juniperus oxycedrus

This association is composed of tree, shrub, and herb layers, distributed at about 1300–1400 m asl on the south-, west-, and southwest-facing slopes. The total coverage of the tree layer is between 80 and 90 %. Characteristic and differential species of the association are *Pinus sylvestris, Juniperus oxycedrus* ssp. *oxycedrus, Lathyrus roseus,* and *Hieracium varigatisquamum.* The components of the Carpino-Acerion and Querco-Carpinetalia orientalis order are well represented in the association (Eminağaoğlu et al. 2007).

15.2.4.5 Pinus sylvestris–Abies nordmanniana ssp. nordmanniana

There are three layers such as tree, shrub, and herb in this association. The total coverage of the tree layer lies between 70 and 90 %. Characteristic and differential species are *Pinus sylvestris, Abies nordmanniana* ssp. *nordmanniana,* and *Delphinium albiflorum.* It is distributed between 1750 and 1850 m asl on the south- and southwest-facing slopes. In this association, the components of the Geranio-Pinion and Pino-Piceetalia orientalis order are well represented (Eminağaoğlu et al. 2007).

15.2.4.6 Abies nordmanniana ssp. nordmanniana–Fagus orientalis

This association is distributed at about 1800–1950 m asl on the north- and northwest-facing slopes, having tree, shrub, and herb layers. The total coverage of the tree layer is between 60 and 90 %. Characteristic and differential species of the association are *Fagus orientalis, Abies nordmanniana* ssp. *nordmanniana, Daphne mezereum, Ranunculus caucasicus* ssp. *subleiocarpus,* and *Astragalus imbricatus.* The components of the Veronico-Fagion and Pino-Piceetalia orientalis order are well presented here (Eminağaoğlu et al. 2007).

Associations given below are mixed shrubby ones distributed in both pure and mixed forests.

15.2.4.7 Rhododendron ungernii–Laurocerasus officinalis

This association has been determined in Fırtına Valley (Rize province), exhibiting two to three vertical tree and shrubby layers; the total coverage of the shrubby layer is 100 % and that of tree layer is less than 40 %. It occupies altitudes between 950 and 1520 m asl, and is a secondary forest succession sere of *Picea orientalis* and *Fagus orientalis* forests. Other than some bryophytes and two fern species, there are no herbaceous taxa found in this association. *Ilex colchica* is the shortest member, with a height of 0.5–1 m. The Castaneo-Carpinion alliance is clearly represented. Characteristic and differential species are *Rhododendron ungernii, Laurocerasus officinalis,* and *Ilex colchica* (Vural 1996).

15.2.4.8 Betula medwediewii–Quercus pontica

This association is found on the south-, west-, southwest-, southeast-, and northwest-facing slopes over Artvin province, and is distributed at the altitudes varying between 1300 and 1700 m asl. There are tree, shrub, and herb vertical layers and the total coverage of the shrub layer is more than 90 %, whereas cover of the tree layer is less than 1 %. The association is highlighted as a member of the Geranio-Pinion alliance and the Pino-Piceetalia orientalis order. Characteristic and differential species are *Quercus pontica, Betula medwediewii, Rhododendron ungernii, Epigaeae gaultherioides, Ruscus colchicus, Veronica peduncularis, Doronicum balansae, Inula helenium* ssp. *orgyalis, Papver lateritium,* and *Helichyrisum artvinense* (Eminağaoğlu and Kutbay 2006).

15.2.5 Subalpine–Alpine Vegetation

15.2.5.1 Polygonum bistorta ssp. carnea–Stachys macrantha

This association is the type of Lilio pontici-Anemonion narcissiflorae alliance. It grows on lower slopes of alpine and subalpine zones, at about 2150–2700 m asl. It is rich in plant diversity and embodies many decorative taxa. There are two vertical layers. Characteristic and differential species are *Polygonum bistorta* ssp. *carneum, Stachys macrantha, Tragopogon aureus,* and *Tripleurospermum monticolum* (Vural 1996; Terzioğlu 1998).

15.2.5.2 Sibbaldia parviflora–Agrostis lazica

It is distributed as a long line from west to east between 2340 and 2850 m asl and has only one vertical layer. The total coverage of the layer is 100 %, reaching 5–20 (-25) cm in height. Characteristic and differential species are *Sibbaldia parviflora, Agrostis lazica,* and *Alchemilla retinervis*. This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Agrostio lazicae-Sibbaldion parviflorae alliance (Vural 1996; Terzioğlu 1998).

15.2.5.3 Centaurea appendicigera–Anthemis cretica ssp. argaea

A type of Centaureo appendicigerae-Senecion taraxacifolii alliance, growing on the slopes of the alpine belt at about 2850–3020 m asl, is affected by erosion. There is only one vertical layer. It has two subassociations: *anthemisetum pectinati* and *senecietosum taraxafoliae*. Characteristic and differential species are *Centaurea appendicigera, Anthemis cretica* ssp. *argaea, Alopecurus glacialis, Alchemill ellenbergiana, Alchemilla rizensis,* and *Huyhnia pulchra* (Vural 1996; Terzioğlu 1998).

15.2.5.4 Lamium album–Saxifraga mollis

It is distributed around 2950–3050 m asl on the northwestern slopes of Kaçkar and Verçenik mountains and has only one vertical layer. The total coverage of the layer is about 40–55 %, reaching 5–20 cm in height. There are two subassociations as *arabietosum caucasae* and *cerastietosum lazici*. Characteristic and differential species are *Lamium album, Saxifraga mollis,* and *Veronica telephiifolia*. This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Centaureo appendicigerae-Senecion taraxacifolii alliance (Vural 1996).

15.2.5.5 Festuca lazistanica–Festuca woronowii

It occurs on the southwestern slopes of Verçenik mountain, between 2890 and 3000 m asl and has two vertical layers. The total coverage of the layer is about 80–90 %, reaching 10–50 cm in height. Characteristic and differential species are *Festuca woronowii* ssp. *woronowii, Festuca woronowii* ssp. *turcica, Chaerophyllum astrantiae, Tanacetum kotschyi, Allium dijimilense, Nonea pulmonaroides, Festuca anatolica* ssp. *borealis, Festuca lazistanica* ssp. *lazistanica, Helictotrichon argaeum,* and *Senecio ovatifolius.* This association is clearly included in the Alchemillo retinervis-Sibbaldietalia parviflorae order and Centaureo appendicigerae-Senecion taraxacifolii alliance (Vural 1996).

15.2.5.6 Rhododendron caucasicum–Vaccinium myrtillus

It is represented by the scrub formation of the alpine zone in the region, dominated by Ericaceae members and the Vaccinio myrtilli-Rhododendrion caucasici alliance. It consists of mainly two layers, the shrubs and herbs. Characteristic species are *Rhododendron caucasicum*, *Vaccinium myrtillus*, *Vaccinium uliginosum,* and *Deschampsia flexiosa*. Vaccinio myrtilli-Rhododendrion caucasici is distributed at 2400–2700 m asl and is represented by *Empetrum nigrum* ssp. *hermaphroditum, Milium schmidtianum, Oxalis acetosella, Rhododendron caucasicum, Solidago virgaurea* ssp. *alpestris, Vaccinium myrtillus,* and *Vaccinium uliginosum* (Vural 1996; Terzioğlu 1998).

15.2.5.7 Nardus stricta–Gentiana pyrenaica

This association is distributed at 2050–2460 m asl along the streams, near the melting snow, over the alpine zone of the eastern Karadeniz region and has only one vertical layer. It is the type of Swertio ibericae-Nardion strictae alliance. The total coverage of the layer is 100 %, reaching 15–25 cm in height. Characteristic and differential species are *Nardus stricta, Gentiana pyrenaica,* and *Poa annua* (Vural 1996; Terzioğlu 1998).

15.2.5.8 Cynosurus cristatus–Ranunculus kotschyi

It is distributed along the streams in the subalpine belt, at about 2000–2035 m asl and has two vertical layers. The total coverage of the layer is 100 %, reaching 15–70 cm in height. Characteristic and differential species are *Cynosurus cristatus, Ranunculus kotschyi, Alchemilla barbatiflora, Myosotis sicula,* and *Ornithogalum platyphyllum.* Members of Gramineae and Cyperaceae families are dominant in both layers. This association is clearly included in the Swertio ibericae-Nardion strictae alliance (Vural 1996).

15.2.6 Wetland Vegetation

15.2.6.1 Lythrum salicaria–Equisetum fluviatile

This association has been reported from Uzungöl (Trabzon province) and is distributed at an altitude of 1050–1100 m asl. It exhibits two vertical layers made up of herbaceous taxa and the total coverage of the layer is about 75 %. This association grows on wetlands alongside the edges of Uzungol Lake. It is a member of the Phragmitetea order. Characteristic and differential species are *Lythrum salicaria, Equisetum fluviatile, Scutellaria galericulata,* and *Thypha shuttlewortthii* (Terzioğlu 1998).

15.3 Factors Threatening Biodiversity

One of the main factors that may cause loss and/or decline of plant diversity at local, regional, national, and/or global scale is the "introduced or naturalized species" (WRI 1992). More than 40 flowering plant taxa have been naturalized in the eastern Karadeniz region of Turkey (Terzioglu and Ansin 2001). The diaspores of the naturalized taxa germinate easily under the favorable climatic conditions of the region and become new individuals. Some of the typical examples are: *Robinia pseudoacacia, Ailanthus altissima, Sicyos angulatus* (Fig. 15.4), *Conyza canadensis, Paspalum dilatatum,* and *Commelina communis.* All have local detrimental effects on the native species. *Sicyos angulatus* is one of the most threatening invasive alien species/an aggressive annual vine in the world and it flourishes in wet areas of the region such as riversides where many native species are seriously threatened by its invasion. It was firstly recorded in 1990s (Terzioğlu and Anşin 1999) from the sea level and in the eastern corner of the region. Unfortunately, it has already been seen throughout the region starting from Artvin to Giresun at altitudes varying between 0 and 1150 m asl.

Some newly recorded invasive alien plant species in the region are *Lysimachia japonica* (Terzioğlu and Karaer 2009), *Acalypha australis* (Duman and Terzioğlu 2009), *Bidens frondosa* (Coşkunçelebi et al. 2007), and *Sigsbeckia pubescens*

Fig. 15.4 *Sicyos angulatus* as an invasive alien species in the region (1–1150 m asl)

(Karaer and Terzioğlu 2013). Another invasive alien species, *Pueraria hirsuta,* an aggressive perennial vine, has been monitored by the authors in Batumi (Georgia), close to the border of the studied region. It is estimated that this species will extend its distribution toward Turkey in a short time. It has been introduced to Georgia from Japan as a decorative plant and has gotten acclimated well, growing in a narrow zone at altitudes varying between 100 and 200 m asl (Kemertelidze et al. 2008).

Other factors that negatively influence the plant diversity in the eastern Karadeniz region of Turkey are:

1. Conversion of forests and grasslands in to agricultural fields
2. Fragmentation of habitats and populations due to the rapid population increase, which results in small and often isolated demes suffering from local extirpation
3. Overexploitation of plant species, which exceeds the ability of species to recover
4. Pollution of soils, water, and atmosphere, which either kill individuals outright or impair their natural functioning
5. Overgrazing.

Some of these factors result from intentional actions taken to meet the needs of a growing human population. Often, however, the changes are undesired results of human actions.

15.4 Climate Change Scenarios for the Region

Analyzing the meteorological data from the stations located in the eastern Karadeniz region from 1951 to 2004, Dalfes et al. (2007) have observed increases in winter and spring precipitations in Artvin, a decrease in spring precipitation in Trabzon, and a decrease in the mean annual temperature in Artvin. In the same report, the future climate of the region has been predicted using a RegCM3 regional climate model.

According to this regional climate model, the temperatures will increase 2–4°C in the region in the next century. Future climate scenarios predict 200–300-mm increases in precipitation in the eastern part of the region while the western part will not have any increase in precipitation in the next century.

15.5 Influences of Climate Change on Biodiversity

Climate change will influence the distribution, structure, stability, and diversity of different ecosystems in the region. With the influence of predicted changes, it is possible to observe 200–400-m upward shifts in the plant belts in the western part of the region and upward movement of the tree line in the eastern part (Figs. 15.5 and 15.6). The upward shift in the tree line will probably threaten the plant diversity of the alpine grassland areas where most of the endemic taxa thrive. An important part of these areas will possibly be covered by spruce or pine forests. According to Tüfekçioğlu et al. (2004), alpine grasslands support 550 plant species, while spruce forests support around 100 plant species.

Temperature increases in the region will put more stress on spruce trees and will probably increase the bark beetle attacks. Around 100,000 spruce trees have been killed by the bark beetle attacks in Hatilla National Park, Artvin (Tüfekçioğlu et al. 2005; Tüfekçioğlu 2008). This will influence the diversity of these forests. Insect-attack-regulated secondary successions will possibly be more common in spruce ecosystem. Especially the members of Ericaea such as *Rhododendron ponticum, R. ungernii, R. x sochadzeae*, and *Vaccinium arctostaphylos* are the dominant species of the secondary succession and they are the allelopathic species which have side effects for the seedlings of oriental spruce and other taxa of the optimal succession.

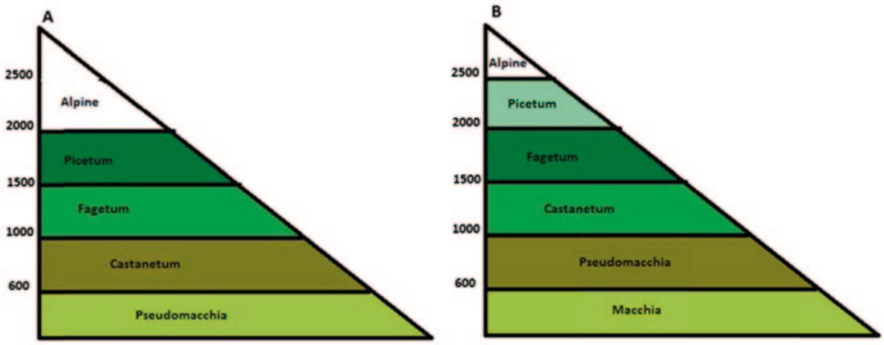

Fig. 15.5 Current (**a**) and expected (**b**) (after 3 °C warming) plant belts in the region

Fig. 15.6 Tree line of *Picea orientalis* in the region

Fire could become an important threat in the western and inner parts of the region with the predicted climate change (Ozturk et al. 2010). Currently, fire is not a problem in oriental spruce ecosystems. These ecosystems in Turkey have a humid climate in summer season; therefore, it is unusual to see fire in these areas. However, fire is an important factor in maintaining the structure, diversity, and health of boreal spruce ecosystems. The influence of fire on the plant diversity of the region will possibly be positive up to a certain level. It will be possible to see fire-induced secondary succession taking place in the western part of the region. Replacement of some spruce and beech forests with the pine forests will increase species diversity in the region because spruce and beech are shade-tolerant species, while pine is a shade-intolerant species. Stands of shade-intolerant species have more plant species in understory compared to shade-tolerant stands.

Conclusions

The plant associations of the high mountainous areas of the eastern Karadeniz region include forests and the subalpine–alpine ecosystems (Table 15.2). According to the predicted climate change, some plant species are expected to move both taxonomically as well as syntaxonomically. In the latter case, the plant associations are expected to move up to 200–400 m according to RegCM3 regional climate model (Dalfes et al. 2007). One of the most important results of this change is that the tree and forest line, especially dominated by oriental spruce, will surge to subalpine upward. It is clear to monitor this possible change in the mentioned area using up-to-date technologies such as geographic information systems (GIS), remote sensing data, satellite images, and aerial photos. Many of the endemic plant taxa are distributed around 1800 m and upward, and predictions are that these plant taxa will be influenced clearly from this change.

The ongoing process of upward movement of vascular plants may not have the same process for each plant taxa. For example, *Taxus baccata* is predicted not to

Table 15.2 Plant associations of eastern Karadeniz region of Turkey distributed at altitude above 1000 m

A. Deciduous forests	B. Mixed deciduous and conifer forests	C. Pure forests	D. Mixed forests	E. Wetland vegetation	F. Subalpine–alpine vegetation
A.1.*Castanea sativa–Fagus orientalis*	B.1. *Fagus orienta-lis–Picea orientalis*	C.1.*Picea orientalis–Sedum stoloniferum*	D.1.*Picea orientalis–Quercus petraea* ssp. *iberica*	E.1.*Lythrum salicaria–Equisetum fluviatile*	F.1. *Polygonum bistorta* subsp. *carnea–Stachys macrantha*
A.2.*Fagus orientalis–Rubus caucasicus*		C.2. *Picea orientalis–Paris incompleta*	D.2.*Picea orientalis–Pinus sylvestris*		F.2.*Sibbaldia parviflora–Agrostis lazica*
		C.3.*Picea orientalis–Telekia speciosa*	D.3. *Picea orientalis–Abies nordmanniana* subsp. *nordmanniana*		F.3.*Centaurea appendici-gera–Anthemis cretica* subsp. *argaea*
		C.4.*Picea orientalis–Doronicum macrolepis*	D.4.*Pinus sylvestris–Juniperus oxycedrus*		F.4. *Lamium album–Saxi-fraga mollis*
		C.5.*Pinus sylvestris–Vaccinium myrtillus*	D.5.*Pinus sylvestris–Abies nordmanniana* subsp. *nordmanniana*		F.5. *Festuca lazistanica–Festuca woronowii*
		C.6. *Pinus sylvestris–Lilium ciliatum*	D.6.*Abies nordmanniana* subsp. *nordmanniana–Fagus orientalis*		F.6.*Rhododendron caucasicum–Vaccinium myrtillus*
		C.7. *Pinus sylvestris–Astragalus adzharicus*	D.7. *Rhododendron ungernii–Laurocerasus officinalis*		F.7. *Nardus stricta–Genti-ana pyrenaica*
		C.8.*Pinus sylvestris–Daphne glomerata*	D.8. *Betula medwed-iewii−Quercus pontica*		F.8.*Cynosurus cristatus–Ranunculus kotschyi*
		C.9.*Pinus sylvestris–Juniperus communis*			
		C.10.*Betula litwinowii–Anemone narcissiflora* ssp. *narcissiflora*			

move easily toward upper levels. Mediterranean elements that occur naturally in the eastern Karadeniz region such as *Pinus pinea* and *Ostrya carpinifolia* too are not predicted to move easily to uplands as expected.

Plant associations distributed at altitudes over 2800 m, such as *Centaurea appendicigera–Anthemis cretica* ssp. *argaea, Lamium album–Saxifraga mollis,* and *Festuca lazistanica–Festuca woronowii,* are expected to lose some of their habitats. Some plant species may become extinct in the alpine and nival vegetation zones due to upward movement toward the mountain peaks. For example, the association *Centaurea appendicigera–Anthemis cretica* ssp. *argaea* is an endemic and may easily be influenced by this shift.

Subalpine and alpine ecosystems are rich in plant species diversity. Endemism ratio is the highest in alpine and nival vegetation in the region with many threatened local endemics such as *Rhodothamnus sessilifolius*. In the peaks of eastern Karadeniz Mountains, snow patches staying throughout the year are important components of plant life in the region and effect the distribution of plant taxa. The persistent snow cover also will be forced to move to upper areas by climate change. Many of the geophytes which are clearly seen in the edge of snow patches may be affected by carrying or completely melted snow.

From a chorological point of view, the alien plant taxa are worth monitoring during the expected change in the climate in the region. Most of the naturalized taxa in Turkey have been recorded in the eastern Karadeniz region (Terzioğlu and Anşin 2001), and the number is expected to increase in the future. On the other hand, the present naturalized alien taxa will move in to new habitats, especially by wind and animals, and the threats of these taxa on the natural ones will increase.

The lower altitudes (< 1000 m) of the region include several different plant associations like:

- *Castanea sativa–Campanula alliarifolia* (Quezel et al. 1980),
- *Carpinus orientalis–Erica arborea* (Quezel et al. 1980),
- *Alnus glutinosa–Oplismenus undulatifolius* (Guner et al. 1987),
- *Rhododendron ponticum–Vaccinium arctostaphylos* (Guner et al. 1987),
- *Alnus glutinosa* ssp. *barbata–Thelypteris limbosperma* (Akman. 1995),
- *Euphorbia paralias–Otanthus maritimus* (Karaer et al. 1997), 0–5 m asl, extremely destroyed by highway construction,
- *Ostrya carpinifolia–Scutellaria albida* ssp. *colchica* (Anşin et al. 2003),
- *Pinus pinea–Crucianella gillani* susbp. *pontica* (Varol et al. 2003).

The Castaneo-Carpinion alliance is well represented at the altitudes less than 1000 m and includes nearly all the mixed deciduous forest of the region. This alliance starts from Ordu in the west and is distributed throughout the eastern Karadeniz region. It is characterized mainly by three subseries *Castanea sativa, Carpinus betulus,* and *Pinus sylvestris* f. *lazica* (Akman 1995).

With the influence of predicted changes, it is possible to observe upward shifts of these syntaxa (except for the *Alnus glutinosa–Oplismenus undulatifolius* association) in the western part of the region. Especially the *Pinus pinea* enclaves in both Trabzon and Artvin provinces are expected to be influenced positively by the predicted changes. These forests are represented with the same plant associations but differ from each other having two subassociations. The climate of these forests is not as rainy as in the most of the region and clearly similar to a Mediterranean climate. It is also estimated that these enclaves, dune, and pseudomacchia vegetation in the lower altitudes will be easily affected. The *Alnus glutinosa–Oplismenus undulatifolius* association is distributed along the river on the alluvions and may easily be affected too.

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Chapter 16
Climate Change Adaptation Strategies of Indonesian Forestry Sector

Cecep Kusmana and Putri Yasmin Nurul Fajri

16.1 Introduction

As the tropical archipelagic country, Indonesia has about 17,504 islands (28 big islands and 17,475 small islands) with the coastline of 95,181 km (Kusmana 2008). It has diverse forest ecosystems which spread from the coast to the mountain area as high as about 4800 m above sea level (masl). It consists of various types of forest ecosystems. There are seven main forest ecosystems in Indonesia. They are monsoon forest, mangrove forest, beach forest, freshwater swamp forest, peat swamp forest, tropical rain forest, and heath forest. Those forests are mainly distributed in seven main islands, comprising of Java, Sumatra, Kalimantan, Sulawesi, Moluccas, Papua, and Nusa Tenggara.

Moreover, owing to the geographical position in an equatorial region between Asia and Australia continents, Indonesian tropical forest possesses high biodiversity (flora and fauna), namely 515 species of mammals (12 % of world mammals, first rank in the world), 511 species of reptiles (7.3 % of world's reptile, third rank in the world), 1531 species of birds (17 % of world's bird, fourth rank in the world), 270 species of amphibians (fifth rank in the world), and 38,000 species of plants (including 4000 species of trees; Nandika 2005).

According to the Ministry of Forestry (2010), there are about 48.8 million people of Indonesia population live in and around the forest, and of which 10.2 million people were categorized as poor community. The number of people whose livelihood was directly from the forest was around 30 million people, with lifestyles of shifting cultivation, fishing, hunting, gathering, tree felling, and sailing wood and non-wood

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forest products (Nandika 2005), and around 3.4 million people worked at private of forestry sector, in which about 205,300 people directly worked at wood processing industries (Ministry of Forestry 2010). Therefore, forests served as dwelling place, source of biodiversity, and source of livelihood for the people.

Referred to the roles of forestry sector above, forestry sector plays a vital role as a buffer of nature balance. Nevertheless, it has undergone a variety of degradation of both natural and anthropogenic factors. Land conversions had occurred with a significant extent. The government through the Directorate of Forestry in 1950 has stated that based on the vegetation maps, about 84 % of Indonesia's land area (162.29 million ha) were covered with primary and secondary forests, including all types of plantations. However, the original natural forest area of Indonesia has been shrinking at an alarming pace. Within the past 3 years, Indonesian forests have undergone degradation with an average of about 1.08 million hectare per year, which is lower than the degradation rate during the 1990s, which was an average of 2.8 million ha. The forest degradation had resulted in the formation of critical land areas of about 30.19 million ha, where 6.89 million ha were categorized as very critical in all over Indonesia (Ministry of Forestry 2010), due to several causes such as illegal logging, forestland encroachment, forest fire, and natural disaster.

Basically, under the situation without climate change, Indonesia is categorized as an area of tropical heat and high humidity (61–95 %), especially in the lowlands and cooler climate in the mountains. The rainy season occurs in November–April and dry season in May–October. However, over time, excessive forest degradation and anthropogenic activities have had strong influence on the existing climate. Many research said that reduction in forest area that serves as a buffer and carbon sinkers has resulted in the abundant increase of greenhouse gases such as CH_4, CO_2, N_2O, SO_2, and CFC, especially with the rise of anthropogenic activities that may significantly affect the climate conditions. Within a long period of time span (50–100 years), this condition can lead to climate change. Actually, climate change has many risks and opportunities in forestry sector, such as increasing of biomasses, landslide, forest fire, etc. Therefore, in this chapter, we discuss about adaptation strategy of climate change at forestry sector based on relevant and believed literatures.

16.2 Climate Change in Indonesia

Climate change in Indonesia is indicated by the change of climate elements as a whole. Indonesia as a tropical country has experienced a trend of change with 0.3 °C increase in its annual average temperature and 2–3 % decrease in its overall rainfall since 1990. Along with an increase of forestland conversion which has resulted in the increase of Indonesia population, wildlife habitat destruction, and overexploitation of forest resources, claimed as the implications of development,

Table 16.1 Total number and location of high- and very-high-disaster-risk regencies. (Source: BAPPENAS (2010))

No.	Type of disaster	Regencies with high- and very-high-risk classes	
		Total (%)	Location
1	Earthquake	193 + 42 = 235 (51.53)	Sumatra (64), Java (56), NTT (26)
2	Tsunami	58 + 13 = 71 (15.57)	Java (19), Sumatra (13), Sulawesi (11)
3	Volcano	81 + 41 = 122 (26.75)	Java (41), Sumatra (22), NTT (9)
4	Landslide	92 + 90 = 182 (39.9)	Sumatra (54), Sulawesi (47), Java (25)
5	Drought	91 + 91 = 182 (39.9)	Java (95), Sumatra (55)
6	Flood	104 + 70 = 174 (38.2)	Java (55), Sumatra (47), Kalimantan(30)
7	Erosion	76 + 118 = 194 (42.6)	Java (72), Sulawesi (33), Sumatra(30)

NTT Nussa Tenggara Timur

has definitely made Indonesia as a region threatened with negative risks of climate change. Table 16.1 shows that within a period of about 50 years, there has been some significantly affected areas due to climate change.

A more recent analysis for Southeast Asia (Yusuf and Francisco 2009) indicates that Indonesia is very vulnerable to various aspects of global warming. The eastern and western parts of Java that are densely populated, most coastal areas of Sumatra, the western and northern parts of Sulawesi, and the islands of southeastern Papua have ranked high on the multiple climate hazard map. Generally speaking, Indonesia is prone to all risks of climate change (drought, floods, landslides, sea level rise), except storm.

Furthermore, the shift in normal years offset by increases in intensity and frequency of ENSO (El Niño Southern Oscillation) and La Niña and Indian Ocean Dipole mode (IODM) as evidences of climate change is predicted to further increase the chances of forest fires and landslides. During El Niño, the Indonesian condition tends to be dry, accompanied with decreased rainfall periods. These conditions could lower the survival of seedlings, increase pests and plant diseases, reduce forest productivity, and increase similar plants. Moreover, if such dry conditions join forces with forest biomass, they could lead to forest fires. Unlike the El Niño, during La Niña, the rainfall periods in most parts of Indonesia are projected to increase as compared to the normal years. This condition will have a negative impact on the forestry sector, especially when an increase in precipitation is accompanied by an increase in forest land-use changes, such as land conversions into industrial, residential, and agricultural activities. Exposure of converted forestlands could result in significant runoff and accumulation of soil materials, leading to landslides and erosions. The increasing incidences of forest fires and landslides, accompanied by changes in climate elements, have threatened biodiversity. In addition, changes in climatology elements have brought threats to forest biodiversity. Sea level rise also has threatened mangrove forest ecosystems and its supporting biological diversity.

Additionally, climate change has caused a variety of potential impacts on forestry sector, including:

1. Reduced seedling survival, increased pests and diseases, reduced forest, and increased invasive species due to decrease in rainfall/drought.
2. Reduced seedling survival rate, alternate growing session, and boundary shapes between grassland and forest due to an increase in temperature.
3. Changes in tree species phenology due to changed rainfall pattern.
4. Changes in forest structure and species composition.
5. Decrease in national income from forestry businesses.
6. Decrease in employment and local livelihood of people-dependent forest.
7. Decrease in river discharge (*water yield*).
8. Increase in erosion and sedimentation.

16.3 Vulnerability, Resilience, and Risk Assessment

16.3.1 Forest Fire

Basically, forest fire requires three conditions to occur, namely biomass as a fuel, oxygen, and fire trigger factors. The relationship between forest fire and climate change is twofold: first, climate change has a significant impact on the area humidity. For example, decreasing humidity of an area could lead to a dry condition that accelerates the distribution of fire causing the occurrence of forest fire. Second, increase in air temperature, precipitation, and CO_2 concentration in the air could accelerate the production of biomass.

Warm and wet climatic conditions, combined with a high carbon dioxide concentration, could increase the growth rate and size of the radial shaft (Hattenschwiller et al. 1997), litter, and roots (IPCC 2007). The high biomass production has implication on the increase of fuel which can lead to forest fires. The future climate change scenarios indicate a change in climatic conditions for the northern part of Indonesia, which becomes warmer and wetter with the increased intensity and frequency of seasonal climate variability such as ENSO or the IODM (Lal et al. 2001). Such projection indicates a high probability of forest fires as a logical implication of the dry condition.

Under normal conditions, the northern parts of Indonesia (northern and central Sumatra, the whole Kalimantan, northern part of Sulawesi and Papua) have wet climate conditions and adequate moisture to avoid the occurrence of forest fires. Similarly, in peat-rich organic components, the normal water table in this area is sufficient to prevent forest fires. However, with the existence of climate change that is causing more and stronger climate variability (ENSO and IODM), the biomass would become drier and water table would decline. This leads to the exposure of large amounts of biomass which speeds up its burning process. The combination of stronger IODM and El Niño could be observed during 1992–1993 and 1997–1998. During such years, extreme drought had occurred that correlated with the increasing number of hot spot(s) in Indonesia.

Huge forest fires could result in a loss of biodiversity, especially on species that are sensitive to forest ecosystem degradation, and even the disappearance of forest stands. Parts of Riau, Central Kalimantan, South Kalimantan, South Sulawesi, West Java, and East Java have a fairly high degree of vulnerability to forest fires. In Sumatra and Kalimantan areas in this decade, peatland fires occurred at an average of 32.1 % and 25.1 %. The number of hot spots in peatland increased and reached its peak in 2005 (in Sumatra) and 2006 (in Kalimantan). Areas with the highest index of forest fires risk occurred along the west coast of West Kalimantan.

16.3.2 Landslide

Landslide incidents in Indonesia are closely related to rainfall and earthquakes. According to Chrisanto's report et al. (2008), there were 49 incidents per year during the periods of 1998–2007. Based on the inventory report system (DesInventar inventory), as many as 890 landslides occurred during the periods of 1998–2009 that had resulted in erosions and killed as many as 1280 people. The global catalog, written by Kirschbaum et al. (2009) in 2003 and from 2007 until 2009, indicated as many as 97 reports of landslides in Indonesia, resulting in 872 victims. According to the Indonesian Geological Agency in 2006–2009, during 2003–2007, rapid landslide occurrences had caused an average of 32 victims per incident. The majority of victims caused by landslides occurred in Java (52 %), East Nusa Tenggara (24 %), and Sumatra (18 %). Landslide disasters have caused not only the loss of lives and buildings but also destructions of significant infrastructures of agricultural land and roads and other economic disruptions. In Indonesia, the western coast of Sumatra, part of Papua Province, some regions of West Java (Sukabumi, Bandung, and surroundings), Central and North Sulawesi, and East Nusa Tenggara Islands were areas with the highest rate of occurrence of landslides.

Landslide occurrence is closely related to the deforestation that is correlated with slope, land cover change on forests, and climate factors (Minnemeyer et al. 2009). A research conducted by Cepeda et al. (2010) stated that 92–96 % of Indonesian landslides occurred in areas with low vulnerability, 0.2–1 % in areas with high vulnerability, and 0.03 % in areas with very high vulnerability. From these statistic figures, Santoso et al. (2008) suggests that an increase in precipitation may increase susceptibility to landslides on slopes of 30°.

16.3.3 Biodiversity

16.3.3.1 Ecosystem Level

At the ecosystem level, the increase in temperature will threaten the mountains and coastal ecosystems. According to Ayres and Lombardero (2000), the increase in temperature can accelerate the growth of insects and diseases, such as the epidemic *Dendroctonus ponderosae* in Canada for several years due to a significant increase in temperature. In addition, warmer temperatures have also influenced the southern pine beetle (*D. frontalis*), resulting in range expansions in the USA. The European rust pathogen *Melampsora Allii-populina* is likely to spread northward with the increase of summer temperatures.

Increased CO_2 levels could enhance the plant biomass that could result in the change of interpopulation interactions (CIFOR 2006), as occurred in the high-latitude regions where *Operophtera brumata* would consume more oak leaves to reduce the thickness of the tree cover. Overall, the increase in CO_2, temperature, and change of rainfall patterns could cause an alteration in species competitiveness and changes in species composition. Changes in species composition due to changes in rainfall patterns (CIFOR 2006) have been observed in North America with the increase of *Bursaphelenchus xylophilus* (Moore et al. 2008).

16.3.3.2 Species Level

At the species level, increase in CO_2 may result in decreased seed mortality, increased recruitment, and increased period for individuals to reach maturity and alteration in individual density (CIFOR 2006). Research by Edwards et al. (2001) stated that a 2-year observation in New Zealand pastures resulted in the number of seedlings that emerged and survived to at least 7 months of age was increased by elevated CO_2 for *H. radicata, Leontodon saxatilis, T. repens,* and *T. subterraneum* in both years and for *A. odoratum* and *Lolium perenne* in the first year. Change in temperature affects the regeneration rate changes and possible increase in tree mortality.

16.3.3.3 Organism Level

At the organism level, increased temperature and CO_2 as well as changes in rainfall patterns could alter species competitiveness and changes in species composition. In addition, increase in CO_2 could also result in an increased growth rate as evidenced in Indonesia forest stands (Baker et al. 1990). Increased CO_2 also affects the increase in water use and seed production. Contrary to the impact caused by increased CO_2 in organism level, changes in rainfall patterns would in fact increase the mortality rate of seedlings (CIFOR 2006).

16.3.3.4 Cell Level

Increase in temperature affects the rate of photosynthesis, photosynthesis period, and increased transpiration at the cellular level. The increased CO_2 at cellular level could accelerate the rate of photosynthesis and reduce stomatal conductance, while changes in rainfall patterns reduce the growth rate of plants (CIFOR 2006).

16.3.4 Sea Level Rise

Global climate change is one of the biggest challenges faced by humans in this century. Although geological record shows that climate change is unavoidable; however, the current level of global warming is clearly threatening the survival of the entire ecosystems. The most vulnerable ecosystem to climate change, especially to sea level rising, is mangrove forest ecosystems. In article by McLeod and Salm (2006), entitled "Managing Mangroves for Resilience to Climate Change," it is stated that the global climate change, specifically rise of sea level, changes in temperature, CO_2, precipitation, and storms combined with anthropogenic threats, will clearly threaten the ecosystem's resilience.

During the twenty-first century, the average sea level rise is projected to range from 0.09 to 0.88 m. In understanding the effect of sea level rise on mangrove ecosystems, the ecological balance of such ecosystem must be considered, including type of substrate, coastal mechanism, tectonic factors, availability of freshwater and sediments, as well as groundwater and salinity. Basically, mangroves can adapt to rising sea level if the rate of sea level rise takes place quite slowly with adequate space expansion and necessary environmental conditions, as observed in Australia. However, if the capacity and supporting factors are not met, it could result in mangrove destruction as found in the Caribbean. Moreover, mangrove ecosystems are also affected by rising global temperatures, changes in temperature, CO_2, precipitation, and storms.

Since 1880, global temperatures have risen by 0.6–0.8 °C and are projected to rise to 2–6 °C by 2100, mostly due to anthropogenic factors. These conditions will also have impacts on mangrove forest ecosystems. The global temperature rise which also increases the sea temperature will have serious impacts on the ecosystem. Sea water temperature above 35 °C has led to the thermal stress which affects the structure of mangrove roots and seedlings. On leaf temperature of 38–40 °C, it is predicted that photosynthesis process would not occur.

McLeod and Salm (2006) noted that CO_2 concentration in the atmosphere has increased from 280 ppmv in 1980 to nearly 370 ppmv in 2000. Such increased CO_2 levels put risk on accelerating the growth rate of mangroves and increased photosynthesis. However, this increase in CO_2 concentrations will have a negative impact on coral reef growth that in turn would negatively impact the mangrove ecosystem. Declining coral reefs could result in lack of protection of the mangrove forest ecosystem against exposure to ocean waves.

Climate change is also marked by changes in rhythm, intensity, and frequency of rainfall. Decrease in rainfall caused a decrease in productivity, growth, and survival of mangrove and might alter the salinity-tolerant species composition. Meanwhile, increased rainfall might increase the extent of mangrove areas, increase the number of mangrove species diversity, and increase the growth rate of some mangrove species.

One of the important elements of climate change that significantly affected mangrove ecosystem is the increased intensity and frequency of storm events and rising sea levels. In the Caribbean, the storm has resulted in the mortality of ten mangrove species over the past 50 years. In addition, increases flooding caused by rainfall storm and rising sea level could result in decreased productivity, decreased photosynthesis, and mangrove survival.

16.4 Implemented Adaptation Measures in Forestry

It is reported that some institutions have been worked on adaptation measures at forestry sector in Indonesia and other countries (Table 16.2). CIFOR (*Center for International Forestry Research*) in TROFCCA (*Tropical Forest and Climate Change Adaptation*) program has done many researches for climate change adaptation. They are mediated between government and communities, connected local wisdom and government in the long-term solution, and mainstreamed government objective to the climate change protection. On the other hand, BAPPENAS in ICCSR (Indonesia Climate Change Sector Report) program and World Bank in CEA (climate change analysis) program have also done the same program for adapting climate change in all sectors.

It is also reported that the Ministry of Forestry has done some programs to enhance the degraded forest area and critical land productivity as well as to enhance the environment quality in relation to climate change, i.e., GERHAN (National Movement for Forest and Land Rehabilitation), One Man One Tree Program, One Billion Indonesian Trees program, and Community-based Forest Management.

Actually, as reported by BAPPENAS (2010), there are a number of existing strategies which address the increasing resilience to the negative impact due to climate change by forestry sector (such as forest fire management, forest and biodiversity conservation, mangrove management), which are anchored in the long-term plan of Ministry of Forestry (2006–2025), but a comprehensive vulnerability analysis still needs to be conducted in order to derive specific activities.

In the RPJM 2010–2014 adaptation, activities are accommodated in two programs, namely (1) the biodiversity conservation and forest protection program and (2) the improvement program for watershed functions and empowerment of watershed-based communities. Supporting programs are the Forestry Research and Development program, Forestry Sector Macro Planning, Stabilization of Forest Area, and Management Support and Technical Task program.

In general term, Indonesia pursues a twofold strategy for mitigation, which reflects the two major function of forest in the context of climate change, i.e., as a carbon source and a carbon sink. Protecting the existing forest will maintain the stock of carbon and its absorption capacity, meanwhile reforestation, and forest rehabilitation will increase the forests' capacity as carbon sink. On the other hand, deforestation and forest degradation will increase emission of greenhouse gases. Key strategies can be summarized as Sustainable Forest Management (SFM), Reducing Emissions from Deforestation and Forest Degradation (REDD+), and plantations. Therefore, mitigation strategy can increase forest sustainability and anticipate a

Table 16.2 Institution work on adaptation measures at forestry sector in Indonesia and other countries

Institution	Program	Result	Action	
CIFOR	TrofCCa	To promote adaptation strategy in forestry sector by tropical forest climate change vulnerability assessment in Indonesia	1.	Landslide adaptation strategy in forestry sector
			2.	Forest fire adaptation strategy in forestry sector
			3.	Social and economy adaptation strategy in forestry sector
World Bank	CEA (Country Environmental Analysis)	This program highlights the economic costs of environmental degradation, and identifies key recommendations to support Indonesian institutions for more sustainable development addressing priority issues of environmental governance and climate change	1.	Repairing forest management system (deforestation, reforestation, and afforestation management)
			2.	Agroforestry promotion for increasing forest productivities
			3.	Developed forest fire management planning
SEAMEO	SEARCA	Climate change adaptation in Philippines	1.	Drought and forest fire adaptation strategy
			2.	Increasing pests and disease adaptation strategy
			3.	Adaptation's strategy of decreased forest productivity due to decreasing rainfall
			4.	Adaptation's strategy of increased invasive species due to drought
			5.	Adaptation's strategy of seedling survival rate due to heat stress
			6.	Adaptation's strategy of altered growing season and boundary shift between grassland and forests due to increasing temperature
			7.	Adaptation's strategy of increased soil erosion and landslides
			8.	Adaptation's strategy of increased rainfall/flooding/sea level rise
BAPPENAS/Ministry of Forestry	ICCSR	Vulnerability and adaptation option (2010–2029)	1.	Review impacts and vulnerability analysis (e.g., on distribution, migration, inter-species interaction), biodiversity conservation and forest protection, with a target of reducing conflict and tension in national parks + other conservation areas, and encroachment of forest areas in 12 priority provinces, increasing buffer zones

Table 16.2 (continued)

Institution	Program	Result	Action	
			2.	Increasing staff and developing human resources for forest fire management and control (e.g., "Forest Fire Supervision Brigade" (BPKH))—community empowerment, land tenure clarification Identification of hot spot by satellite, develop fire break, establishment of community fire fighter, revitalization of fire prevention tools, demonstration of land clearing without burning
			3.	Reviewing match species—site conditions, vulnerability analysis, adaptive management, including mixed native species to enhance resilience of silvicultural systems
			4.	Research (adaptive capacity of mangroves, coastal forests) and mangrove reforestation
BAPPENAS/Ministry of Forestry	ICCSR	Vulnerability and adaptation option (2010–2029)	1.	Enhancing communities' capacity to manage forests by making rights to forest management certain, institutional strengthening, participation and active role of the stakeholders)
			2.	Adaptive forest management, including mixed native species to enhance resilience of silvicultural systems
			3.	Research and development, forest product diversification to increase economical resilience of the sector

CIFOR Center for International Forestry Research, *SEAMEO* Southeast Asian Ministers of Education Organization, *SEARCA* Southeast Asian Regional Center for Graduate Study and Research in Agriculture, *ICCSR* Indonesia Climate Change Sector Report

great resilience of the climate change. Thus, mitigation strategy can be followed by adaptation strategy from the increased climate change resilience.

In this context, the mitigation strategy held by Ministry of Forestry is also categorized as adaptation measures in order to enhance the resilience of forest ecosystems, local communities lived in and surrounding the forest, and for guaranteeing the raw material sustainability of forestry industry.

16.5 Possible Adaptation Strategies/Actions/Options in Short, Medium, and Long Term

Considering the important role of forest resources as well as the environmental services of forest ecosystem and the estimated vulnerabilities of Indonesian forestry sector, there are three adaptation strategies for the climate change to ensure the sustainability of forestry sector development in Indonesia, which are as follows: (1) increasing the resilience of forest ecosystem, (2) increasing the resilience of local communities, and (3) maintaining the sustainability of forestry industry. Those strategies can be run through the technology, policy, and social economic options (Table 16.3). Meanwhile, BAPPENAS (2010) has identified climate hazards, vulnerabilities, and indicatives adaptation actions of forestry sector as shown in Table 16.4.

In the forestry sector, SEARCA (2011) states that further adaptation strategies that can be implemented in response to the decline in rainfall include the use of drought-resistant seeds, improving efforts to protect forests, enhancing responsiveness to forest fires through technology, community development, determination of species that are resistant to the risk of forest fires, and species that are resistant to climate extremes. In addition, adaptations to declining rainfall that impacted on reduced water yield can be dealt with irrigation technology and reduced the possibility of forest degradation. Besides the reduction in rainfall, there is also the possibility of increased rainfall which affects the risk of flooding and landslides. Adaptation strategies that could be implemented include redesigning erosion control systems and planting of vegetation species that are resistant to landslides. Furthermore, changes in rainfall patterns could be determined through phenology distribution and updating seed collection calendar in seed production. Adaptation to temperature increases can be done by breeding plants that are resistant to temperature stress using drought-tolerant species to overcome the problem of declining rainfall that resulted in reduced seedlings' survival.

Based on such strategy, it is necessary to integrate policy makers and practitioners as well as the society as a whole in adapting to climate change, especially in forestry sector. Through such adaptation formulation, it is expected to create a civil society capable of adapting to climate change threats. Thus, this could help in creating more established life sustainability and could increase security in forestry sector that could result in good forest management systems, including regulation of deforestation, reforestation and afforestation, agroforestry promotion to improve products and services of forestry, the development/improvement of forest fire management plans, and improvement of carbon storage by forests.

Table 16.3 Possible adaptation options and actions of the forestry sector to climate change

No.	Option		Short term	Medium term	Long term
1	Technology	Technology	Identification of hot spot by satellite Identification of landslide high-risk area Identification of critical degree of watersheds Revitalization of fire prevention materials and equipment Development of infrastructure to control forest fire and landslide Biodiversity conservation and forest protection Develop fire break Demonstration of land clearing burning	Application of sustainable forest management using silvicultural multisystem for production of forest Application of soil and water conservation techniques, either vegetative or civil engineering techniques to control forest, landslide, as well as erosion Rehabilitation/restoration degraded forests and critical land Application of reduce impact logging system Increasing buffer zone Establishment of forest plantation on unproductive critical forest area	Application of forest management unity system (Kesatuan Pengelolaan Hutan/KPH) for production forest (KPHP), protection forest (KPHL), and conservation forest (KPHHK) Application efficient and environmental friendship technique in forest product processing Application of agroforestry Adaptive forest management, including mixed native species to enhance resilience of silvicultural system
		Information and knowledge	Maps of dispersion of hot spots, forest fire hazard index, landslide hazard index, and critical land Maps of vulnerability and risk index of forest types Collection and organization information on biophysical environments and social economic on forestry sector Review impact and vulnerability analysis on forest biodiversity Reviewing match species-site conditions Vulnerability analysis	Studies on the adaptive capability of various species of flora and fauna (especially endangered and protection species) to climate change Development of proper monitoring and evaluation of applied technology on adaptation measures Manual of technologies in enhancing the adaptive capacity to climate change Adaptive capacity of mangroves, beach forest and montana, submontana forest Research and development of forest products diversification, mainly non-wood forest product and environmental services Proper techniques on forest rehabilitation/restoration	Upgrading monitoring system (long-term monitoring) for each forest ecosystem Information availability on flora/fauna species resistance to fire, land movement (flora), drought, and flooding

Table 16.3 (continued)

No.	Option		Short term	Medium term	Long term
2	Policy	Legal system	Regulation to protect forests ecosystem from anthropogenic factors (illegal logging, illegal smuggling, forest land encroachment, forest land conversion, forest fire, etc.) Regulation on forest utilization, forest rehabilitation, and forest management	Enhancing the value of forest from non-wood forest products and environmental services viewpoint Conflict resolution concerning forestland tenure Revitalization of forest production, forest protection, and forest conservation	Regulation on empowerment local community in forest management and forest utilization Stabilization of forest area Regulation on incentive system in managing forest and forest rehabilitation/restoration
		Human resources	Implementation of training/education for decision maker, volunteers, local people, and private company to manage adaptation measures in enhancing adaptive capacity to climate change	Increasing staff and developing human resources for forest fire management and control (i.e., Forest Fire Supervision Brigade) Provision of information (manuals and other reference media) for improving the knowledge and skill of the trainer Upgrading the competency of human resources in monitoring and evaluation of adaptation measures	Human resources development in preventing, maintaining, and enhancing the value of forest as well as the resilience of forest ecosystem to climate change
3	Social economy	Social system	Community empowerment in participating the forest management and forest rehabilitation/restoration Land tenure clarification	Establishment of village forest, people forest, and community forest	Enhancing the employee of forestry sector, either from viewpoint of silvicultural works, forest products processing and marketing, or ecotourism and environmental services Managing forest in supporting the food, energy, and medicine securities
		Economy system	Establishment of incentive for forest utilization, forest management and forest rehabilitation/restoration REDD+	Regulations on economy system to stimulate the sustainable forest management	Establishing a specific financial mechanism to funding the forestry sector development, mainly forest rehabilitation/restoration

REDD+ Reducing Emissions from Deforestation and Forest Degradation

Table 16.4 Identified climate hazards, vulnerabilities, and indicative adaptation actions of forestry sector. (Source: BAPPENAS (2010))

System perturbation and hazard	Current vulnerabilities		Indicative adaptation action
1. Forest resources	Climatic	Anthropogenic, land use, and other stressors	
Forest biodiversity	Changing site condition by temperature and precipitation patterns	Forest exploitation, alternation of species competition, forest fires	Review impact and vulnerability analysis (e.g., on distribution, migration, inter-species interaction), biodiversity conservation and forest protection with a target of reducing conflict and tension in national parks + other conservation areas, and encroachment of forest area in 12 provinces, increasing buffer zone
Forest fire	ENSO occurrence, droughts, temperature increase	Forest degradation	Increasing staff and developing human resources for BPK forest fire management and control (e.g., "Forest Fire Supervision Brigade" BPKH)—community empowerment, land tenure clarification identification of hot spot by satellite, developed fire break, establishment of community firefighter, revitalization on fire prevention tools, demonstration of land clearing without burning
Forest productivity and changed site conditions		Forest degradation	Reviewing match species site condition, vulnerability analysis, adaptive management, including mixed native species to enhance resilience of silvicultural system
Mangrove/coastal forest recession	Extreme event (waves, storm)	Coastal erosion, intensive mangrove use	Research (adaptive capacity of mangroves, coastal forests) and mangrove reforestation
2. On forest dependent people/livelihoods	Climatic	Anthropogenic, land use and other stressors	
Income/livelihoods	Extreme events (landslide, erosion, drought, fires)	Dwindling with degrading forest resources	Enhancing communities' capacity to manage forest by making rights to forest management, certain institutional strengthening, participation and active role of the stakeholders
Cultural/traditional value system		Dwindling with degrading forest resources	
Possible assessment tool: sustainable livelihoods framework and community-based risk assessment tools			

Table 16.4 (continued)

System perturbation and hazard	Current vulnerabilities		Indicative adaptation action
3. Forest industries	Climatic	Anthropogenic, land use and other stressors	
Forest plantations Productivity decline	Extreme events (wind drought)	Monocultures, low-level genetic variation	Adaptive forest management, including mixed native species to enhance resilience of silvicultural system
Negative impact on wood based industries		Gap between wood supply and demand by industry	Research and development, forest product diversification to increase economical resilience of the sector
Suggested assessment method: combination of plant–soil maps and economic model (e.g., CGE model)			

CGE computable general equilibrium

16.6 Recommendation for Mainstreaming Adaptation into National Development Planning

Currently, there are several regulations and laws that support climate change policy in forestry sector, namely:

(a) Minister of Forestry Regulation No. P14/2004 on Afforestation and Reforestation in the Framework of Clean Development Mechanism.
(b) Minister of Forestry Regulation No. P68/2008 on Implementation of Demonstration Activities to Reduce Carbon Emission from Forest Deforestation and Degradation.
(c) Minister of Forestry Regulation No. P30/2009 on The Implementation Procedures of Reducing Emissions from Deforestation and Forest Degradation (REDD).
(d) Minister of Forestry Regulation No. P36/2009 on Licensing Procedure for Absorption of Carbon Utilization in Production Forest and Protection Forest.

The effectiveness of the implementation of the above four Minister of Forestry Regulations is supported by the following regulations and laws:

(a) Law No. 41/1999 on Forestry.
(b) Law No. 26/2007 on Spatial Planning
(c) Law No. 6/1994 on Ratification of UNFCCC.
(d) Law No. 17/2004 on Ratification of Kyoto Protocol to the UNFCCC.
(e) Presidential Regulation No. 61/2011 on National Action Plan for Reducing Greenhouse Gas Emissions.

(f) Presidential Regulation No. 71/2011 on Implementation of a National Greenhouse Gases Inventory.
(g) Government Regulation No. 6/2007 (revised by PP No. 3/2008) on Forest Products Utilization Framework including Environmental Services.
(h) Presidential Instruction No. 4/2005 on Combating Illegal Logging.
(i) Presidential Instruction No. 10/2011 on the Postponement of Issuance of New Licenses of Primary Natural Forest and Peatland.

In order to ensure the synergy of the implementation of all acts and regulations mentioned above, there are some gaps/barriers that must be overcome to attain successful implementation and mainstreaming climate change adaptation of forestry sector, namely:

(a) Lack of institutional capacity building (human resources, governance, support system), especially at local-level government.
(b) Lack of technology and equipments.
(c) Inappropriate stakeholders' (mainly local people) empowerments.
(d) Unsatisfied dissemination of regulations to various community levels, especially the local people.
(e) Lack of accurate data, yet Indonesia includes large variations on climatic and geographical conditions.
(f) Limited budget for executing the adaptation measures at local level.

To address the gaps/barriers mentioned above, it is recommended to optimize the coordination between the forestry sector with other related sectors, both in implementing the policies of the sector and cross-sectoral policy, such as in the implementation of Presidential Instruction No. 5/2011 and MP3EI. In relation to this, it is necessary to strengthen policies concerning:

(a) Enhancement of institutional capacity building (human resource and governance).
(b) Strengthening of the technological capacity and its support system.
(c) Intensification of regulations dissemination and community empowerment.
(d) Allocation of sufficient fund for adaptation.
(e) Establishment of monitoring and evaluation system (including criteria and indicators) for the success of adaptation measures.

As for improving the resilience and adaptability of forest ecosystems to climate change in forestry sector, the Ministry of Forestry has established six priority policies (2011–2015), namely:

(1) Forest area establishment.
(2) Forest rehabilitation and increasing watershed carrying capacity.
(3) Forest protection and forest fire control.
(4) Biodiversity conservation.
(5) Revitalization of forest and forestry industry.
(6) Community empowerment.

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Chapter 17
Floral Diversity of the High Altitudes of Amanos Mountains: A Case Study from Daz Mountain-Mıgır, Turkey

Necattin Turkmen, Atabay Duzenli and Münir Öztürk

17.1 Introduction

The region below the snow line but above the tree line on the high mountains of temperate and tropical areas is delimited as the alpine zone. Its lower limits vary in different regions of the world. In Turkey, it lies above 1800 m following the subalpine zone below it. The zone is typically occupying the area approximately above 2000 m. The subalpine zone shows a scanty tree cover and is dominated by dwarf shrubs and moist meadow communities, later forming a transition zone. As the altitude increases on the high-altitude ecosystems, rainfall, wind, evaporation, and direct solar radiation increase. However, temperature, oxygen, atmospheric pressure, and nitrogen mineralization decrease (Guleryuz et al. 2010). Moreover, ecological features of the northern and southern slopes differ to a greater extent. Accordingly, different types of vegetation belts are formed and the vegetation period gets shortened under the influence of different altitudes (Atay et al. 2009; Sarı 2010).

Since the ice age, climate change has affected the geographical distribution of different ecosystems, leading towards a spread of the alpine vegetation zones in the vertical direction. However, the plant taxa show specific changes and adapt to the environmental conditions as well as climate changes differently. Consequently, in the past, different species were occurring at high altitudes in place of such communities. A change in the environmental conditions leads to species migrations, species compositions, and the emergence of new taxa; this process is actually continuing even now.

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A total of 8000–10,000 taxa of flowering plants are reported to grow globally in the alpine belts, which is 4% of the world's approximately 250,000 species of flowering plants (Ozturk et al. 2010a). Very difficult and adverse conditions prevail at these high altitudes; however, the plant diversity still is quite high compared to several areas at low elevations (Ozturk et al. 1991, 2002; Körner 1995; Atay et al. 2009).

The plants growing in the alpine environment under harsh climatic conditions accordingly show adaptations in the shape; with stunted appearances, height is smaller and majority are herbaceous except for some shrubs. Adaptive forms of plants (called Krummholz) in this difficult environment enable them to be more resistant to the severe cold and snow. Almost all are perennials with underground root or even stems (Kılınç and Kutbay 2004).

The alpine plants also called orophytes (for example Poaceae and Cyperaceae) have developed adaptive features against the extreme environmental conditions existing at high altitudes like hard sometimes pointed and often rounded leaves. They possess vivid showy flowers with bright colors as in Orchidaceae, Primulaceae, and Gentianaceae.

Some dwarf shrubs and herbaceous plant formations dominate these altitudes at 2000 m. Some of the representatives are: *Juniperus communis, Juniperus nana,* and *Daphne oleoides,* forming very closed communities at places. The species of *Festuca, Verbascum,* and *Thymus* are the most common herbaceous plants distributed here (Uysal et al. 2011). The most common plant genera found here are: *Acantholimon, Alchemilla, Allium, Alyssum, Astragalus, Bellis, Campanula, Carex, Centaurea, Crocus, Dianthus, Draba, Gentiana, Gypsophila, Papaver, Potentilla, Primula, Ranunculus, Salvia, Saxifraga, Sedum, Silene,* and *Veronica* (Sarı 2010).

The mountainous areas in general are very important in terms of biodiversity, in particular the endemic plants (Uysal et al. 2011). The ratios of endemism are very high; more endemic species are present here. If the invading species spread here, they will lose the opportunity to grow, or the extensive areas covered currently will gradually decrease, leading to a withdrawal of these plants, although under present conditions, the species growing on the mountainous areas restrict the invasions to some extent (Efe et al. 2008, 2011a, 2011b, 2012, 2014a, 2014b).

Turkey, with its rich plant diversity of over 10,000 taxa, occupies an important position in the Southwest Asia (Davis 1965–1985; Davis et al. 1988; Guner et al. 2000; Ozturk et al. 2008a, 2012a, b). The reasons for this are that the country is situated at an important geographical location bridging three continents, which has been further encouraged by its history, topography, geology, and different climatic conditions. The floral elements distributed in different phytogeographical regions embody different elements and a high ratio of endemics is a natural consequence of all these characteristics. Therefore, the country has attracted the attention of hundreds of investigators, particularly from 1701 onwards. In this chapter, detailed information on the plant diversity of Mıgır hill, with an altitude of 2240 m (Daz Mountains) as the highest peak of Amanos Mountains, located on the eastern coast of the Gulf of Iskenderun, will be provided with possible implications of future climate change scenarios.

Fig. 17.1 General view and location of the study area

17.2 Study Area

The area investigated by us is situated in the province of Hatay in southeastern part of Turkey (along the Gulf of Iskenderun), between 35°36′45″ and 36°28′50″ east longitudes and 36°44′40″–37°04′15″ north latitudes. The subalpine vegetation forms a wide belt on the mountain of Daz in particular on Mıgır hill with an altitude of 2240 m (Fig. 17.1). Erzin, Ozerli, Deliçay, and Payas streams take their origin from this area and flow down into the Gulf of Iskenderun.

Geologically, this area is formed from Mesozoic and Cretaceous limestones, upper Cretaceous ultrabasic rocks (Gabro and Serpentine), and Tertiary marls. The plains in the area consist of quaternary alluvial materials. Common soil formations distinguished in the area are as follows: brown calcareous soils, brown forest soils, terrarosa soils, reddish-brown Mediterranean soils, colluvial soils, and mixed land types (Akman 1973). The summers here are hot and dry, but winters are mild and rainy as the Mediterranean climate prevails all through this region (Ozturk 1995; Ozturk et al. 2008a; Ozkan et al. 2010). Annual rainfall varies between 921.9 and 1500 mm, depending on the elevation and direction. Seasonal rainfall regime is as follows: winter, spring, autumn, and summer. From the beginning of December until the end of March, precipitation in the form of snow is seen at places above 1000 m. The average annual temperature of the area is 19.3 °C. In August, average maximum temperature is 32.8 °C and the minimum average temperature of 6 °C is seen in January. Ombrothermal climate diagram, derived from Dortyol meteorological station climatic data and covering the period between 2000 and 2012 is presented in Fig. 17.2.

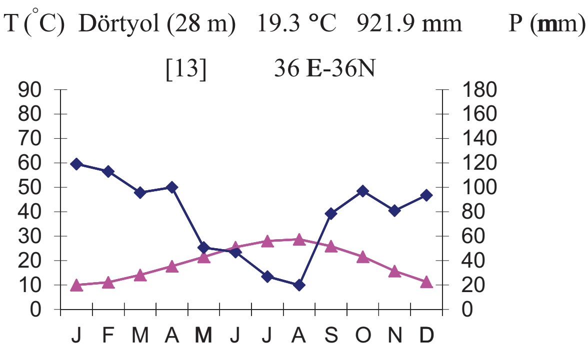

Fig. 17.2 Ombrothermic diagram of the study area. The dry period in June–October, the rainy period (>100 mm) in February

17.3 Plant Diversity

Our investigations on the specimens collected from the area and identified with the help of flora of Turkey (Davis 1965–1985; Davis et al. 1988; Guner et al. 2000) have revealed that 660 vascular plant taxa belonging to 387 genera from 98 families are distributed here (Appendix). All the herbarium specimens have been deposited at the "Herbarium of the Science and Arts Faculty—Çukurova University (ADA) and include information on their phytogeographical region as: Med. = Mediterranean, Euro-Sib. = Euro-Siberian, Ir-Tur. = Irano-Turanian, End. = Endemic.

The phytogeographical distribution of these taxa is as follows (Table 17.1): Mediterranean 196 (29.7 %); Euro-Siberian 71 (10.8 %); Irano-Turanian 41 (6.2 %); Cosmopolitan and unknown 353 (53.3 %). The total number of endemics is 53 and the ratio of endemism is 8 %.

The Mediterranean elements are dominating the list simply due to the prevalence of Mediterranean climate here. The Euro-Siberian elements, which were widely distributed in the Pleistocene ice age, have progressed southwards along the Anatolian Diagonal, and due to the humid climatic conditions, they are still continuing to grow in the study area (Davis et al. 1971). The Euro-Siberian floristic region in Turkey is a very widespread area with typical *Fagus orientalis* forest formation. In the Mıgır hill, large, frequent, and pure community is distributed on the northern slopes between 1600 and 1900 m, (Yilmaz 1993; Kehl 1998; Turkmen and Duzenli 1998).

The dominating families and the number of taxa these embody are: Leguminosae, 78 (11.8 %); Compositae, 74 (11.2 %); Gramineae, 48 (7.3 %); Labiatae,

Table 17.1 A comparison of the phytogeographical elements in the study area

Phytogeographic region	Number of species	Percent of sample total
Mediterranean	196	29.7
Euro-Siberian	71	10.8
Irano-Turanian	41	6.2
Multiregional	353	53.4

Table 17.2 The families represented with 12 and more species in the study area

Family	Distribution	%
Fabaceae	78	11.8
Asteraceae	74	11.2
Poaceae	48	7.3
Lamiaceae	41	6.2
Liliaceae	30	4.5
Brassicaceae	30	4.5
Rosaceae	25	3.8
Caryophyllaceae	21	3.2
Scrophulariaceae	21	3.2
Apiaceae	19	2.9
Boraginaceae	17	2.6
Rubiaceae	17	2.6
Orchidaceae	12	1.8
Others	227	34.4

41 (6.2%); Cruciferae, 30 (4.5%); Liliaceae, 30 (4.5%); Rosaceae, 25 (3.7%); Scrophulariaceae, 21 (3.2%), Umbelliferae, 19 (2.8); Caryophyllaceae, 17 (2.5%), Boraginaceae, 17 (2.5%), and Rubiaceae 17 (2.5%) (Table 17.2).

The rare and endemic species and their International Union for Conservation of Nature (IUCN) categories are as follows: CR: 1 EN: 1, VU: 15, DD: 2, NT: 12, and LC: 22 (Table 17.3) IUCN (Ekim et al. 2000; IUCN 2011).

In the study area, the Mediterranean, sub-Mediterranean, and subalpine plant belts also exist (Altan 1984; Atalay 1987).

Mediterranean Belt This zone exists up to 850 m and above with hard-leaved evergreen plants. *Pinus brutia* forests cover the lower areas. Most common species are: *Quercus coccifera, Erica manipuliflora, Rhamnus punctatus, Rinanthus angustifolius, Pistacia terebinthus* ssp. *palaestina, Cotinus coggyre, Phyllyre latifolia* ssp. *orientalis, Myrtus communis* ssp. *communis, Arbutus andrachne, Styrax officinalis, Cistus creticus,* and *Calicotome villosa*.

Sub-Mediterranean Belt It is distributed between 850 and 1900 m, the end of the forest limit with deciduous plants. Common species include *Fagus orientalis, Pinus brutia, Quercus cerris* var. *cerris, Pinus nigra* ssp. *pallasiana, Carpinus orientalis, Cedrus libani,* and *Abies cilicica* (Gucel et al. 2008).

Subalpine Belt This belt starts from 1900 m extending up to the summit of this mountain (2240 m). The steppe vegetation with herbaceous species and shrubs dominates the belt. Most common species are: *Acantholimon libanoticum, Marrubium globosum* ssp. *globosum, Astragalus macrourus, Ferula elaeochytris, Rosa pulverulenta Cerasus prostrate* var. *prostrata, Cotoneaster nummularia, Vincetoxicum tmoleum, Asperula stricta* ssp. *monticola, Thymus kotschyanus* var. *glabres-*

Table 17.3 The endangered species of the study area and their IUCN red data list categories

Endangered plants	Conservation status
Centaurea cataonica Boiss. & Hausskn.	NT
C. lycopifolia Boiss. & Kotschy	NT
C. ptosimopappa Hayek Med.	VU (B1 a,b and B2 a,b)
Galatella amani (Post) Grierson	VU (B1 a,b and B2 a,b)
Helichrysum arenarium (L.) Moench ssp. *aucheri* (Boiss.) Davis et Kupicha	LC
Inula anatolica Boiss.	LC
Leucocyclus formosus Boiss. ssp. *amanicus* (Rech. fil.) Hub.-Mor. & Grierson	NT
Pilosella hoppeana (Schultes) C.H. & F.W. Schultz ssp. *isaurica* Hub.-Mor.	LC
Alkanna amana Rech. fil.	DD
Onosma inexspectatum Teppner	LC
Aethionema capitatum Boiss. & Ball.	NT
Alyssum murale Waldst. & Kit. var. *haradjianii* (Rech.) Dudley	VU (B1 a,b and B2 a,b)
Erysimum alpestre Kotschy ex Boiss.	LC
Isatis candolleana Boiss.	LC
Ricotia sinuata Boiss. & Heldr.	LC
Thlaspi densiflorum Boiss. et Kotschy	NT
T. elegans Boiss.	VU (B1 a,b and B2 a,b)
T. violascens Boiss.	LC
Michauxia tchihatchewii (Boiss.) Hand.-Mazz.	NT
Phryna orthegioides (Fisch. & C.A. Mey.) Pax & K. Hoffm.	NT
Cephalaria taurica Szabo	VU (B1 a,b and B2 a,b)
Scabiosa kurdica Post	VU (B1 a,b and B2 a,b)
Euphorbia rhytidosperma Boiss. & Bal.	VU (B1 a,b and B2 a,b)
Astragalus antiochinus Post	DD
A. campylosema Boiss. ssp. *campylosema*	LC
Chamaecytisus drepanolobus (Boiss.) Rothm.	NT
Lathyrus laxiflorus (Desf.) Kuntze ssp. *angustifolius* (Post ex Dinsm.) Davis	VU (B1 a,b and B2 a,b)
Trifolium davisii Hossain	VU (B1 a,b and B2 a,b)
Vicia canescens Lab. ssp. *canescens*	NT
Quercus petraea (Mat.) Liebl. ssp. *pinnatiloba* (C. Koch) Menitsby	LC
Herniaria saxatilis Brummitt	VU (B1 a,b and B2 a,b)
Crocus cancellatus Herbert ssp. *cancellatus* Herbert	LC
Gladiolus anatolicus (Boiss.) Stapf	LC
Lamium microphyllum Boiss.	VU (B1 a,b and B2 a,b)

Table 17.3 (continued)

Endangered plants	Conservation status
Marrubium globosum Montbret et Aucher ex Bentham ssp. *globosum*	LC
Phlomis longifolia Boiss. & Bal. var. *bailanica* (Vierh.) Hub.-Mor.	NT
Satureja amani P.H. Davis	CR (B1 a,b and B2 a,b)
Scutulleria glaphyrostachys Rech. fil.	VU (B1 a,b and B2 a,b)
S. rubicunda Hormem ssp. *brevibracteata* (Stapf.) Edmond	LC
S. salviifolia Bentham	LC
Thymus sipyleus Boiss. ssp. *sipyleus* var. *sipyleus*	NT
Alcea apterocarpa (Fenzl.) Boiss.	LC
Fraxinus ornus L. ssp. *cilicica* (Lingels.) Yalt.	LC
Dactylorhiza osmanica (L.) Soo' var. *osmanica*	LC
Acanthalimon acerosum (Willd.) Boiss. var. *brachystachyum* Boiss.	VU (B1 a,b and B2 a,b)
Festuca adanensis Markgr.-Dannenb.	NT
Potentilla calycina Boiss. and Bal.	LC
Asperula cymulosa (Post) Post	VU (B1 a,b and B2 a,b)
A. stricta Boiss. ssp. *monticola* Ehrend.	LC
Verbascum caesareum Boiss.	VU (B1 a,b and B2 a,b)
V. cheiranthifolium Boiss. var. *asperilum* (Boiss.) Murb.	LC
V. linearilobium (Boiss.) Hub.-Mor.	EN (B1 a,b and B2 a,b)
Veronica orientalis Boiss. Miller ssp. *nimordi* (Reichter ex Stapf.) M.A. Fischer	LC

CR (B1 a,b and B2 a,b) Critically endangered: Extent of occurrence less than 5000 km^2 ; area of occupancy less than 500 km^2 ; known no more than five locations; inferred decline in the area, extent and/or quality of habitat, *EN* (B1 a,b and B2 a,b) Endangered: Extent of occurrence less than 100 km^2 ; area of occupancy less than 10 km^2 ; known to exist at only a single location; inferred decline in the area, extent and/or quality of habitat, *VU* (B1 a,b and B2 a,b) Vulnerable: Extent of occurrence less than 20,000 km^2 ; area of occupancy less than 2000 km^2 ; known no more than ten locations; inferred decline in the area, extent, and/or quality of habitat, *NT* Near threatened, *LC* Least concern

cens, Verbascum amanum, Asphodelina damascene ssp. *damascene, Echinops ritro, Eremurus spectabilis, Carpinus orientalis, Cedrus libani,* and *Abies cilicica.* The reasons for the rich and interesting plant diversity in this area are that it is the main distribution area for the eastern Black Sea and central European deciduous plant species. These Euro-Siberian floristic elements (*Fagus orientalis, Acer platonoides, Alnus glutinosa* ssp. *glutinosa, Populus tremula, Salix alba* ssp. *alba, Coryllus avellena* ssp. *avellena, Eonymus latifolius* ssp. *latifolius, Buxus sempervirens, Tilia argentea, Ulmus glabra, Sorbus torminalis* ssp. *torminalis, Sambucus nigra, Sambucus ebulus, Ilex colchica, Atropa belladonna, Eupotarium cannabinum,* and

Solanum dulcamara) are growing approximately 400–500 km away from their natural habitats, forming the southernmost distribution area of these plant taxa. We also see this area as the main distribution site of Lebanon and Anti-Lebanon region, containing the species like *Quercus libani, Satureja amani, Astragalus antiochianus, Rhamnus libanoticus, Pyrus syriacus* var. *syriaca,* and *Acantholimon libanoticum*. The area thus forms the northernmost area for these plants.

17.4 Climate Change

The study area is situated in the Mediterranean zone of Turkey. It is already facing threats due to human interferences, land degradation, and fires, and the situation will get escalated due to climate change and is expected to be felt most seriously in the eastern Mediterranean which includes our study area as well (Ozturk et al. 2008a, 2010b, 2011). A global climate change will affect species and ecosystems. The existing vegetation in the study area will be affected substantially by this change because of the special topography, climate, and geographical location of this area. The life cycle of plants corresponds to the seasonal cues, so any shifts in the timing of such cycles will be reflected here; accelerated spring onset will generate noticeable changes in such phonological features like timings of plants, first bud bursts, first leafing, first flowerings, and first seed or fruit dispersal of species. All these will prove detrimental if an area is prone to cold. Any cold spell occurring a few days or weeks after early blooming will mean that early buds or fruits will freeze; the rare and interesting species at these altitudes, including the economically important plants, will be potentially killed or their production will be hindered. The study area is a highly interesting habitat; it is like an enclave for the Euro-Siberian and several other elements in the Mediterranean. In view of this, there is a need for intensive and immediate research into the effects of climatic fluctuations on the plants of this area in general (Feoli et al. 2003). The predicted climate scenarios on temperature increases will interfere with the hydrological conditions, thus seriously threatening the survival of cryo-hygrophilous high-altitude plant taxa in the Amanos area. The endemics will get full share from all these impacts. The upward migrations due to warming temperatures will end up with the shifting patterns in the vegetation belts here, followed by drought-tolerant invaders from lower altitudes, ultimately leading towards biodiversity losses (Ozturk et al. 2008b; Ozkan et al. 2010; Guleryuz et al. 2010; Uysal et al. 2011).

17.5 Appendix

The Floristic List

Aceraceae

Acer platanoides L. Euro-Sib

Adiantaceae
Adiantum capillis-veneris L.
Amaranthaceae
Amaranthus blitoides S. Wats.
A. chlorostachys Willd.
A. lividus L.
A. retroflexus L.
Anacardiaceae
Cotinus coggyria Scop.
Pistacia terebinthus L. ssp. *palaestina* (Boiss.) Engler
Rhus coriaria L.
Apiaceae (umbelliferae)
Ainsworthia trachycarpa Boiss. Med.
Ammi majus L. Med.
Bunium ferulaceum Sm. Med.
Bupleurum intermedium Poiret
Cnidium silaifolium (Jacq.) Simonkai ssp. *orientalis* (Boiss.) Tutin
Daucus guttatus Sm.
Eryngium creticum Lam. Med
E. falcatum Delar Med.
Ferula elaeochytris Korovin Med.
Ferulago cassia Boiss. Med.
F. trachycarpa Boiss.
Laser trilobium (L.) Borkh.
Laserpitium glaucum Post Med.
Lecokia cretica (Lam.) DC.
Sanicula europaea L. Euro-Sib
Smyrnium connatum Boiss. & Kotschy Med.
Torilis arvensis (Huds.) Link ssp. *neglecta* (Sprengel) Thellung
T. arvensis (Huds.) Link ssp. *arvensis*
Turgeniopsus foeniculacea (Fenzl.) Boiss.
Apocynaceae
Nerium oleander L. Med.
Vinca major L. ssp. *major* Med.
Aquifoliaceae
Ilex colchica Poj. Euro-Sib
Araceae
Arum dioscoridis Sm. var. *liepoldtii* (Scott) Engler Med.
Araliaceae
Hedera helix L.
Asclepiadaceae
Vincetoxicum tmoleum Boiss. Ir-Tur
Aspidiaceae
Polystichum setiferum (Forssk.) Woynar.
Dryopteris filix-mas (L.) Schott. Med.

D. pallida (Bory) Fomin.

Aspleniaceae

Asplenium adiantum-nigrum L.

A. cuneifolium Viv.

A. septentrionale (L.) Hoffm. ssp. *septentrionale* (L.) Hoffm.

A. trichomanes L.

Ceterach officinarum DC.

Phyllitis sclopenendrium (L.) Newm.

Asteraceae (compositae)

Achillea coarctata Poir.

A. grandiflora Friv.

Anthemis kotschyana BOISS. var. *radians* Bornm.

A. tinctoria L. var. *tinctoria*

Arctium minus (Hill) Bernh. ssp. *pubens* (Babington) Arenes Euro-Sib

Bellis perennis L. Euro-Sib

Carduus amanus Rech. fil..

Carlina oligocephala Boiss. & Kotschy ssp. *oligocephala* carpa Moris Med.

Centaurea aegialophila Wagenitz Med.

C. aucheri (DC.) Wagenitz *Ir-Tur*

C. babylonica (L.) L. Med

C. calcitrapa L. ssp. *calcitrapa* Med.

C. cataonica Boiss. & Hausskn. End

C. lycopifolia Boiss. & Kotschy Med. End

C. ptosimopappa Hayek Med. End

C. solstitialis L. ssp. *solstitialis*

Calendula arvensis L.

Cardopatium corymbosum (L.) Pers. Med.

Carduus nutans L. ssp. *nutans*

C. pycnocephalus L. ssp. *albidus* (Bieb.) Kazmi

Chrysanthemum segetum L. Med.

Cichorium pumilum Jack Med.

Cirsium leuconeurum Boiss. & Hausskn.

Condrilla juncea L. *var. juncea*

Conyza bonariensis (L.) Cronquist

C. canadensis (L.) Cronquist

Crepis reuterana Boiss. ssp. *reuterana*

C. sancta (L.) Babcock

Doronicum orientale Hoffm.

Echinops ritro L.

E. viscosus DC. ssp. *bithynicus* (Boiss.) Rech. fil.

Eupotarium cannabinum L.

Galatella amani (Post) Grierson Med. End

Gundelia tournefortii L. var. *tournefortii*

Hedypnois cretica (L.) Dum.-Cours. Med.

Helichrysum arenarium (L.) Moench ssp. *aucheri* (Boiss.) Davis et Kupicha Ir-Tur End
H. armenium DC. ssp. *armenium*
H. plicatum DC. ssp. *plicatum*
Helminthotheca echioides (L.) Holub. Med.
Hieracium laevigatum Willd. Euro-Sib
Hypochoeris radicata L. var. *heterocarpa* Moris Euro-Sib
Inula anatolica Boiss. End
I. salicina L. Euro-Sib
I. vulgaris (Lam.) Trevisan Euro-Sib
Lapsana saligna L.
L. *serriola* L. Euro-Sib
Lapsana communis L. ssp. *intermedia* (Bieb.) Hayek
L. *communis* L. ssp. *psidica* (Boiss. & Heldr.) Rech. fil.
Leontodon hispidus L. var. *hispidus*
Leucocyclus formosus Boiss. ssp. *amanicus* (Rech. fil.) Hub.-Mor. & Grierson Med. End
Onopordum acanthium L.
Pallenis spinosa (L.) Cass. Med.
Picnomon acarna (L.) Cass. Med.
Picris amalecitana (Boiss.) Eig Med.
Pilosella echioides (Lumn.) C.H. & F.W. Schultz ssp. *procera* (Fries) Sell & West
P. hoppeana (Schul.) C.H. & F.W. Schultz ssp. *troica*
P. hoppeana (Schultes) C.H. & F.W. Schultz ssp. *isaurica* Hub.-Mor. Ir-Tur End
Ptilostemon diacantha (Lab.) Greuter Med.
Pulicaria dysenterica (L.) Bernh.
Reichardia intermedia (Schultz Bip.) Hayek Med.
Rhagadiolus stellatus (L.) Gaertner var. *edulis* (Gaert.) DC. Med.
Scorzonera cana (C.A. Meyer) Hoffm. var. *cana* Cosm.
S. cana (C.A. Meyer) Hoffm. var. *radicosa* (Boiss.) Chamb.
S. mollis Bieb. ssp. *szowitzii* (DC.) Chamb. Ir-Tur
Senecio vernalis Waldst & Kit.
Silybum marianum (L.) Gaertner
Sonchus oleraceus L.
Steptorhampus tuberosus (Jacq.) Grossh.
Taraxacum sintensii Dahlst.
Tripleurospermum oreades (Boiss.) Rech. fil. var. *oreades* (Boiss.) Rech. f.
Tyrimnus leucographus (L.) Cass. Med.
Urospermum picroides (L.) F.W. Schmidt. Med.
Xanthium spinosum L.
X. strumarium L. ssp. *cavenillesii* (Scho.) D. Love & P. Dansr.

Athyriaceae
Athyrium filix-foemina (L.) Roth.

Betulaceae

Alnus glutinosa (L.) Gaertn. ssp. *barbata* (C.A. Meyer) Yalt. Euro-Sib

Boraginaceae

Alkanna amana Rech. Fil. Med. End
Anchusa strigosa Labill.
A. undulata L. ssp. *hybrida* (Ten.) Coutinho
Brunnera orientalis (Scheyk) Johnston Euro-Sib
Buglossoides arvensis (L.) Johnston
Cynoglossum creticum L.
C. montanum L. Grande ssp. *cariense* (Boiss.) R. Mill var. *cariense*
Heliotrophium europaeum L. Med.
Lithodora hispidula (Sm.) Griseb. ssp. *versicolor* Meikle Med.
Lithospermum purpurocaeruleum L. Euro-Sib
Myosotis lithospermifolia (Willd.) Hornem. Euro-Sib
M. alpestris F.W. Schmidt.
Onosma frutescens Lam Med.
O. inexspectatum Teppner Med. End
O. tauricum Patlas ex Willd. var. *tauricum*
Paracaryum lithospermifolium (Lam.) Med.
Symphytum brachycalix Boiss. Med.

Brassicaceae (cruciferae)

Aethionema capitatum Boiss. & Ball. End.
Alyssum cassium Boiss. Med.
A. condensatum Boiss. & Hauskn. ssp. *flexibile* (Nyar) Dudley
A. desertorum Stapf. *var. prostratum* Dudley
A. minus (L.) *Rothm.* var. *micranthum* (Meyer) Dudley
A. murale Waldst. & Kit. var. *haradjianii* (Rech.) Dudley End.
A. samariferum Boiss. & Hsusskn.
A. strictum Willd. Ir-Tur
A. strigosum Banks & Sol. ssp. *strigosum*
Arabis caucasica Willd. ssp. *brevifolia* (DC.) Cullen Med.
A. caucasica Willd. ssp. *caucasica*
A. turrita L.
Capsella bursa-pastoris (L.) Medik.
Cardaria draba (L.) Desv. ssp. *draba*
Erysimum alpestre Kotschy ex Boiss. Ir-Tur End.
E. goniocaulon Boiss.
Iberis spruneri Jord. Med.
I. taurica DC.
Isatis candolleana Boiss. Ir-Tur End.
Neslia apiculata Fisch.
Raphanus raphanistrum L.
Ricotia sinuata Boiss. & Heldr. Med. End.
Sisymbrium altissimum L. ssp. *flexibile* (Nyar) Dudley
Thlaspi annuun Koch
T. densiflorum Boiss. et Kotschy End.

T. elegans Boiss. Med. End.
T. praeocox Wulf Euro-Sib
T. oxyceras (Boiss.) Hedge
T. kotschyanum Boiss. & Hohen.
T. violascens Boiss. End.
Turritis glabra L.
T. laxa (Sibth. & Sm.) Hayek

Buxaceae
Buxus sempervirens L. Euro-Sib

Campanulaceae
Asyneuma virgatum (Labill.) Bornm. ssp. *virgatum*
Campanula aucheri A. DC. Euro-Sib
C. postii (Boiss.) Engler Med.
C. rapunculus L. var. *rapunculus* Euro-Sib
C. retrorsa Labill.
C. trachelium L. ssp. *athoa* (Boiss. & Heldr.) Hayek Euro-Sib
Legousia speculum-veneris (L.) Chaix Med.
Michauxia campanuloides L'Herit. ex Aiton Med.

Capparaceae
Capparis spinosa L. var. *spinosa*

Caprifoliaceae
Lonicera xylosteum L.
Sambucus ebulus L. Euro-Sib
S. nigra L. Euro-Sib

Caryophyllaceae
Arenaria leptoclados (Reichb.) Gauss.
Cerastium saccardoanum Dirat
C. glomeratum Thuill. Cosm.
Dianthus polycladus Boiss. Med.
D. orientalis Adams
Gypsophila libanotica Boiss. Med.
Minuartia hybrida (Vill.) Schischk. ssp. *hybrida*
M. mesogitana (Boiss.) Hand.-Mazz. ssp. *mesogitana* Med.
M. tchihatchewii (Boiss.) Hand.-Mazz. End.
Moehringia trinervia (L.) Clairv.
Petrorhagia velutina (Guss.) Ball & Heyward
Phryna orthegioides (Fisch. & C.A. Mey.) Pax & K. Hoffm. Ir-Tur End
Polycarpon tetraphyllum (L.) L.
Silene aegyptiaca (L.) L. fil. ssp. *aegyptiaca*
S. compacta Fischer
S. confertiflora Chowdh.
S. flavescens Waldst. & Kit.
S. italica (L.) Pers.
S. odontopetala Fenzl
S. vulgaris (Moench) Garcke var. vulgaris

Telephium imperati L. ssp. *orientale* (Boiss.) Nyman
Vaccaria pyramidata var. grandiflora (Fisch. ex DC.) Cullen
Celastraceae
Euanymus latifolius (L.) Mill. ssp. *latifolius* Euro-Sib
Chenopodiaceae
Chenopodium album L. ssp. *album* var. *album*
C. foliosum (Moench.) Aschers.
Cistaceae
Cistus creticus L. Med.
C. salviifolius L.
Fumana arabica (L.) Spach var. *arabica*
F. thymifolia (L.) Variot var. *thymifolia* Med.
Helianthemum ledifolium (L.) Miller var. *microcarpum* Willk.
H. nummularium (L.) Miller ssp. *tomentosum* (Scop.) Schnz et Thellung
Convolvulacae
Calystegia silvatica (Kit.) Griseb.
Convolvulus arvensis L. Cosm.
C. dorycnium L. ssp. *oxycephalus* (Boiss.) Rech. fil Med.
Cornaceae
Cornus mas L. Euro-Sib
C. sanguinea L. ssp. *australis* (C.A. Mey.) Jav. Euro-Sib
Corylaceae
Carpinus orientalis Miller
Corylus avellana L. var. *avellana* Euro-Sib
Ostrya carpinifolia Scop. Med.
Crassulaceae
Rosularia libanotica (Lab.) Muirhead Med
Sedum album L.
S. caespitosum (Cav.) DC. Med.
S. hispanicum L. var. *hispanicum*
S. pallidum Bieb. var. *pallidum*
S. rubens L. Med.
Cupressaceae
Juniperus oxycedrus L. ssp. *oxycedrus*
Cuscutaceae
Cuscuta brevistyla A. Braun
C. campestris Yuncker Cosm.
Cyperaceae
Bolboschoenus maritimus (L.) Palla var. *cymosus*
Carex distans L. Euro-Sib
C. divulsa Stokes subsp. *divulsa* Eur-Sib
C. flacca Schreber ssp. *serrulata* (Biv.) Greuter Med.
C. pendula Hudson Euro-Sib
Cyperus rotundus L.
Scirpoides holoschoenus (L.) Sojak

Dioscareaceae
Tamus communis L. ssp. *communis*
Dipsaceae
Cephalaria taurica Szabo Med. End
Scabiosa calocephala Boiss.
S. columbaria L. ssp. *columbaria var. intermedia* (Post) Matws.
S. columbaria L. ssp. *ochroleuca* (L.) Coulter var. *webbiana* (Don) Matws
S. kurdica Post Med. End
Ephedraceae
Ephedra campylopoda C.A. Meyer
Equisetaceae
Equisetum palustre L.
Ericaceae
Arbutus andrachne L.
A. unedo L.
Erica manipuliflora Salisb. Med.
Euphorbiaceae
Mercurialis annua L.
M. ovata Sternb. & Hoppe Euro-Sib.,
Euphorbia herniariifolia Willd. var. *glaberrima* Hal. Med.
E. supina Rafin
E. rhytidosperma Boiss. & Bal. Med., End
E. apios L. var. *lamprocarpa* Boiss. Med.
E. helioscopia L.
E. peplus L. var. *peplus*
E. falcata L. ssp. *falcata* var. *falcata*
E. macrostegia Boiss.
Fabaceae (leguminosae)
Alhagi mannifera Desv.
Astragalus antiochinus Post Med. End
A. campylosema Boiss. ssp. *campylosema* Ir-Tur End
A. depressus L.
A. glycyphyllos L. ssp. *glycyphylloides* (DC.) Matws. Ir-Tur
A. hamosus L.
A. macrourus Fisch. & Mey. Ir-Tur
A. russelii Banks & Sol. Ir-Tur
A. schizopterus Boiss. Med.
A. thiebautii Eig Med.
Calicotome villosa (Poiret) Link Med.
Ceratonia siliqua L. Med.
Cercis siliquastrum L. ssp. *hebecarpa* (Bornm.) Yalt.
Chamaecytisus drepanolobus (Boiss.) Rothm. Med. End
C. hirsutus (L.) Link
Colutea cilicica Boiss. et Bal.
Coronilla emerus L. ssp. *emerus* (Boiss. & Sprun.) Uhrova

C. parviflora Willd. Med.
Cytisopsis dorycniifolia Jaub. & Spach. ssp. *dorycniifolia*
Dorycnium graecum (L.) Ser. Euro-Sib
D. hirsutum (L.) Ser. Med.
D. pentaphyllum Scop. ssp. *haussknechtii* (Boiss.) Gams
Genista anatolica Boiss. Med.
G. lydia Boiss. var. *antiochia* (Boiss.) P. Gibbs. Med.
G. lydia Boiss. var. *lydia*
Gonocytisus angulatus (L.) Spach Med.
Hymenocarpus circinnatus (L.) Savi Med.
Lathyrus annuus L. Med.
L. *aphaca* L. *var. modestus* P.H. Davis Med.
L. *laxiflorus* (Desf.) Kuntze ssp. *angustifolius* (Post ex Dinsm.) Davis Med. End.
L. *niger* (L.) Bernh. ssp. *niger* Euro-Sib
L. *spathulatus* Cel. Med.
Lens ervoides (Brign.) Grande Med.
Lotus angustissimus L.
L. *corniculatus* L. var. *corniculatus*
L. *peregrinus* L. var. *peregrinus*
Lupinus angustifolius L. ssp. *angustifolius*
Medicago coronota (L.) Bart. Med.
M. lupulina L.
M. minima (L.) Bart. var. *minima*
M. polymorpha L. var. *vulgaris* (Benth.) Shinners
M. rigidula (L.) All. var. *rigidula*
Melilotus elegans Salzm. Med.
M. indica (L.) All.
Onobrychis caput-galli (L.) Lam. Med.
O. gracilis Besser
Ononis phyllocephala Boiss. Med.
O. reclinata L. Med.
O. spinosa L. ssp. *leiosperma* (Boiss.) Sirj.
Prosopis farcta (Banks & Sol.) Macbride
Psoralea bituminosa L. Med.
Scorpiurus muricatus L. var. *subvillosus* (L.) Fiori Med.
Sophora jaubertii Spach Euro-Sib
Spartium junceum L. Med.
Tetragonolobus purpureus Moench Med.
Trifolium angustifolium L. var. *angustifolium*
T. arvense L. var. *arvense*
T. campestre Schreb.
T. davisii Hossain Med. End
T. fragiferum L. var. *pulchellum* Lange
T. hirtum All. Med.
T. lappaceum L. Med.

T. lucanicum Gasp. Med.
T. physoides Stev. ex Bieb. var. *physoides* Med.
T. physoides Stev. ex Bieb. var. *psilocalyx* Boiss. Med.
T. purpureum Boiss. var. *pamphylicum* (Boiss. & Heldr.) Zoh. Med.
T. resupinatum L. var. *microcephalum* Zoh.
T. tomentosum L.
T. tumens Stev. ex Bieb. Euro-Sib
Trigonella kotschyi Fenzl Ir-Tur
T. spruneriana Boiss. var. *sibthorpii* (Boiss.) Hub.- Mor. Med.
Vicia canescens Lab. ssp. *canescens* Ir-Tur End
V. cracca L. ssp. *cracca* Euro-Sib
V. crocea (Desf.) B. Fedtsch. Euro-Sib
V. grandiflora Scop. *var. grandiflora* Med.
V. hybrida L.
V. lunata (Boiss. & Bal.) Boiss. var. *grandiflora* Plitm.
V. sativa L. ssp. *sativa* Cosm.
V. villosa Roth ssp. *eriocarpa* (Hausskn.) P.W. Ball

Fagaceae
Castanea sativa Miller Euro-Sib
Fagus orientalis Lipsky. Euro-Sib
Quercus cerris L. var. *cerris* Med.
Q. coccifera L. Med.
Q. infectoria Oliver ssp. *boissieri* (Reuter) O. Schwarz
Q. libani Oliver Ir-Tur
Q. petraea (Mat.) Liebl. ssp. *pinnatiloba* (C. Koch) Menitsby End

Gentianaceae
Blackstonia perfoliata (L.) Hudson ssp. *serotina* (W. Koch ex Reichb.) Vollmann
Centaurium erythraea Rafin. ssp. *turcicum* (Velen) Melderis

Geraniaceae
Erodium acaule (L.) Becherer & Thell. Med.
Geranium columbinum L.
G. libanoticum Schenk
G. molle L. ssp. *molle*
G. purpureum Vill.
G. robertianum L.
G. tuberosum L. ssp. *tuberosum*

Hypericaceae (guttiferae)
Hypericum confertum Choisy ssp. *stenobotrys* (Boiss.) Holmb.
H. elongatum Ledeb. ssp. *microcalycinum* (Boiss.& Heldr.) Robson Ir-Tur
H. montbreti Spach
H. origanifolium Willd.
H. perforatum L.
H. thymifolium Banks. et Sol. Med.

Hypolepidaceae
Pteridium aquilinum (L.) Kuhn

Illecebraceae

Herniaria hirsuta L.
H. saxatilis Brummitt End.
Paronychia argentea Lam var. *scariossima* Post Med.
Scleranthus annuus L. ssp. *annuus*

Iridaceae

Crocus cancellatus Herbert ssp. *cancellatus* Herbert Med. End
C. kotschyanus C. Koch ssp. *kotschyanus*
Gladiolus anatolicus (Boiss.) Stapf Med. End
G. italicus (Boiss.) Stapf
Gynandriris sisyrinchium (L.) Parl.
Iris unguicularis Poiret Med.

Juglandaceae

Juglans regia Miller

Juncaceae

Juncus inflexus L.
Luzula forsteri (Sm.) DC. Euro-Sib

Lamiaceae (labiatae)

Ajuga chamaepitys (L.) Schreber bsp. *chia* (Schreber) Arcangeli var. *ciliata* Briq.
A. orientalis L.
Ballota nigra L. ssp. *nigra* (Fiori & Beg.) Petzak Med.
Calamintha grandiflora (L.) Moench Euro-Sib
C. nepeta (L.) Savi ssp. *nepeta* Med.
Clinopodium vulgare L. ssp. *arundanum* (Boiss.) Nyman
Lamium garganicum L. ssp. *nepetifolium* (Boiss.) R. Mill.
L. *garganicum* L. ssp. *reniforme* (Montbret & Aucher ex Bentham) R. Mill. Med.
L. *macrodon* Boiss. & Huet Ir-Tur
L. *maculatum* L. var. *maculatum* Euro-Sib
L. *microphyllum* Boiss. Med. End
L. *truncatum Boiss.* Med.
Marrubium globosum Montbret et Aucher ex Bentham ssp. *globosum* Ir-Tur End
Melissa officinalis L. ssp. *officinalis*
Mentha pulegium L.
Micromeria fruticosa (L.) Druce ssp. *barbata* (Boiss. et Kotschy) DAVIS *Med.*
Nepeta cilicica Boiss. Med.
Origanum laevigatum Boiss. var. *laxum* Post Med.
O. syriacum L. *var. bevanii* (Holmes) Leswaart Med.
Phlomis longifolia Boiss. & Bal. var. *bailanica* (Vierh.) Hub.-Mor. Med. End
P. viscosa Poiret Med.
Prunella orientalis Bornm.
P. vulgaris L. Euro-Sib
Salvia glutinosa L. Euro-Sib
S. viridis L. Med.
S. tomentosa Miller Med.
Satureja amani P.H. Davis Med. End

Scutulleria glaphyrostachys Rech. fil. Med. End
S. rubicunda Hormem ssp. *brevibracteata* (Stapf.) Edmond Med. End
S. salviifolia Bentham End
Sideritis libanotica Labill. ssp. *libanotica* Med.
S. perfoliata L. var. *condensata* Boiss.
Stachys annua (L.) L. ssp. *ammophila* (Boiss. & Bl.) Samuel. Med.
S. diversifolia Boiss. Med.
S. pinetorum Boiss. & Bal. Med.
Teucrium polium L. var. *vulgare* Bentham
Thymbra spicata L. var. *spicata* Med.
Thymus leuchotrichus Hal. var. *austroanatolicus* Jales
T. kotschyanus Boiss. & Hohen var. *glabrescens* Boiss. Ir-Tur
T. sipyleus Boiss. ssp. *sipyleus* var. *sipyleus* End
Ziziphora capitata L. ssp. *orientalis* Samuel. ex Rech. Ir-Tur

Lauraceae
Laurus nobilis L. Med.

Liliaceae
Alllium ampeloprasum L. Med.
A. calyptratum Boiss. Med.
A. lycaonicum Siehe ex Hayek
A. scorodoprasum L. ssp. *rotundum* (L.) Stearn Med.
A. sipyleum Boiss. Med.
Asparagus acutifolius L. Med.
Asphodelina globifera J. Gay ex Baker Med.
A. damascena (Boiss.) Baker ssp. *damascena* Ir-Tur
Asphodelus aestivus Brot. Med.
Colchicum cilicicum (Boiss.) Dammer Med.
C. trodii Kotschy Med.
Danae racemosa (L.) Moench
Eremurus spectabilis Bieb. Ir-Tur
Fritillaria acmopetale Boiss. ssp. *acmopetale* Med.
F. hermonis Fenzl ssp. *amana* Rix Med.
F. pinardii Boiss. Ir-Tur
Gagea fibrosa (Desf.) Schultes & Schultes. fil.
Muscari comosum (L.) Mill.
M. neglectum Guss.
M. tenuiflorum Tousch.
Ornithogalum oligophyllum E.D. Clarke
O. ulophyllum Hand.-Mazz.
Polygonatum multiflorum All.
P. orientale Desf. Euro-Sib
Ruscus aculeatus L. var. *angustifolius* Boiss.
Scilla autumnalis L.
S. melaine Speta Med.
Smilax aspera L.

S. excelsa L. Euro-Sib
Urginea maritima L. Med.
Linaceae
Linum aroanium Boiss. & Orph.
L. *bienne* Miller Med.
Loranthaceae
Loranthus europaeus Jacq.
Malvaceae
Alcea apterocarpa (Fenzl.) Boiss. Ir-Tur End.
Althaea cannabina L.
Malva neglecta Waldr.
Moraceae
Ficus carica L. ssp. *carica*
Myrtaceae
Myrtus communis L. ssp. *communis*
Oleaceae
Fraxinus ornus L. ssp. *cilicica* (Lingels.) Yalt. Med. End
Jasminum fruticans L. Med.
Olea europaea L. var. *sylvestris* (Miller) Lehr. Med.
Phillyrea latifolia L. ssp. *orientalis* Sebst. Med.
Onagraceae
Epilobium montanum L. Euro-Sib
Orchidaceae
Anacamptis pyramidalis (L.) L.C.M. Richard Med.
Cephalanthera kurdica Bornm. ex Kranzlin Ir-Tur
C. damasonium (Miller) Druce Euro-Sib
C. longifolia (L.) Fritsch Euro-Sib
C. rubra (L.) L.C.M. Richard
Dactylorhiza osmanica (L.) Soo' var. osmanica Ir-Tur End
D. saccifera (Brong.) Soo' Med.
Epipactis helleborine (L.) Crantz
Limodorum abortivum (L.) Swartz
Orchis mascula (L.) ssp. *pinetorum* (Boiss. & Kotschy) G. Camus Med.
O. morio L. ssp. *syriaca* Camus et al. Med.
Platanthera bifolia (L.) L.C.M. Richard Euro-Sib
Orobanchaceae
Orobanche anatolica Boiss. & Reuter
O. caryophyllacaea Smith
O. crenata Forsskal
Phelypaea coccinea (Bieb.) Poiret Ir-Tur
Oxalidaceae
Oxalis corniculata L. Cosm.
Paeoniaceae
Paeonia mascula (L.) Miller ssp. *mascula*
Papaveraceae

Corydalis alpestris C.A. Meyer Euro-Sib
C. rutifolia (Sibth.& Sm.) DC. ssp. *erdelii* (Zucc.) Cullen & Davis
Hypecoum procumbens L.
Papaver rhoeas L.
P. syriacum Boiss. & Blanche

Phytolaccaceae
Phytolacca pruniosa Fenzl Med.

Pinaceae
Abies cilicica (Ant.& Kotschy) Carr. ssp. *cilicica*
Cedrus libani A. Rich.
Pinus brutia Ten.
P. nigra Arnold. ssp. *pallasiana* (Lamb.) Holmboe

Plantaginaceae
Plantago holosteum Scop. Med.
P. lanceolata L.
P. major L. ssp. *intermedia* (Gilib.) Lange
P. scabra Moench

Platanacae
Platanus orientalis L.

Plumbaginaceae
Acanthalimon acerosum (Willd.) Boiss. var. *brachystachyum* Boiss. Ir-Tur End.
A. libanoticum Boiss. Med.
A. venustum Boiss. var. *venestum* Boiss. Ir-Tur

Poaceae (gramineae)
Aegilops neglecta REq. ex Bertol. Med.
A. speltoides Tausch var. *speltoides*
Agrostis stolonifera L. Euro-Sib
Alepocurus gerardii Vill. var. *gerardii* Med.
Arrhenatherum palaestinum Boiss. Med.
Brachypodium pinnatum (L.) P. Beauv.
Briza minor L.
Bromus intermedius Guss.
B. scoparius L.
B. squarrosus L.
B. sterilis L.
B. tectorum L.
Catapodium rigidum (L.) C.E. Hubbard ex Dony ssp. *rigidum var. majus* (C. Persl) Lainz
Chrysopogon gryllus (L.) Trin.
Crypsis alopecuroides (Piller & Mitterp.) Schrader
Cynodon dactylon (L.) Pers. var. *dactylon*
Cynosurus echinatus L. Med.
Dactylis glomerata L. ssp. *glomerata*
D. glomerata L. ssp. *hispanica* (Roth) Nyman
Dicanthium annulatum (Forsskal.) Stapf. Ir-Tur

Digitaria sanguinalis (L.) Scop.
Echinaria capitata (L.) Scop.
Echinochloa colonum (L.) Link
Eromopoa songarica (Schrenk) Roshev. Ir-Tur
Festuca adanensis Markgr.-Dannenb. End
F. jeanpertii (St.-Yves) F. Markgraf apud Hayek ssp. *jeanpertii* (St.-Yves) f. Markgraf apud Hayek Med.
Hordeum bulbosum L.
Hyparrhenia hirta (L.) Stapf.
Lolium rigidum Gaudin var. *rigidum*
Melica eligulata Boiss. Med.
M. minuta L. Med.
M. uniflora Retz Euro-Sib
Paspalum paspaloides (Michx.) Schribner
Phleum montanum C. Koch ssp. *montanum*
Phragmites australis (Cav.) Trin. Ex Steudel Euro-Sib
Piptatherum coerulescens (Desf.) P. Beauv.
Poa annua L. Cosmp.
P. bulbosa L.
P. nemoralis L.
P. timoleontis Heldr. ex Boiss. Med.
Saccharum ravennae (L.) Murray
S. strictum (Host) Sprengel
Sorghum halepense (L.) Pers. var. *halepense* Steudel
Stipa holosericea Trin Ir-Tur
Themeda triandra Forsskal.
Tragus racemosus (L.) All.
Vulpia fasciculata (Forsskal) Fritsch Med.

Polygalaceae
Polygala comosa Schkur
P. supina Schreb.

Polygonaceae
Polygonum arenarium Euro-Sib
P. aviculare L. Cosm.
P. convolvulus L.
P. persicaria L.
P. polycnemoides Saub. & Spach Ir-Tur
Rumex acetosella L. Cosm.
R. angustifolius Campd. ssp. *angustifolius* Ir-Tur
R. chalepensis Miller
R. conglomeratus Murray
R. pulcher L.

Polypodiaceae
Polypodium australe Fee.
P. vulgare L. ssp. *vulgare*

Portulacaceae
Portulaca oleracea L.
Primulaceae
Anagallis arvensis L. var. *caerulea* (L.) Gouan
Cyclamen coum Miller var. *coum*
Primula vulgaris Huds. ssp. *vulgaris* Euro-Sib
Punicaceae
Punica granatum L.
Raflesiaceae
Cytinus hypocistis L. ssp. *kermesinus* (Guss.) Waldts. Med.
Ranunculaceae
Adonis annua L.
Clematis flammula L. Med.
C. vitalba L.
Ranunculus chius DC.
R. cuneatus Boiss.
Thalictrum orientale Boiss. Med.
Rhamnaceae
Paliurus spina-christi Miller
Rhamnus alaternus L. Med.
R. libanoticus Boiss.
R. punctatus Boiss. var. *angustifolius* Post Med.
Rosaceae
Cerasus prostrata (Lab.) Ser. var. *prostrata*
Cotoneaster nummularia Fisch.& Mey.
Crateagus atrosanguinea Pojark. Ir-Tur
C. monogyna Jacq. ssp. *azarella* (Gris.) France
C. monogyna Jacq. ssp. *monogyna*
C. orientalis Pallas ex Bieb. var. *orientalis*
Fragaria vesca L.
Geum urbanum L. Euro-Sib
Malus sylvestris Miller ssp. *orientalis* (A. Uglitz.) Browicz var. *orientalis*
Potentilla aucheriana Th. Wolf Ir-Tur
P. calycina Boiss. and Bal. Med. End
Potentilla crantzii (Crantz) G. Beck ex Fritsch var. *crantzii* (Crantz) G. Beck ex Fritsch Euro-Sib
P. kotschyana Fenzl Med.
P. micrantha Remond ex DC.
P. speciosa Willd. var. *discolor* Hal.
Prunus divaricata Ledeb. ssp. *divaricata*
P. spinosa L. ssp. *dasyphylla* (Schur) Domin Euro-Sib
Pyracantha coccinea Roemer
Pyrus syriaca Boiss. var. *syriaca*
Rosa canina L.
R. pulverulenta Bieb.

Rubus sanctus Schreber
R. canescens DC. var. *glabratus* (Godron) Davis et Meikle Euro-Sib
Sanguisorba minor Scop. ssp. *muricata* (Spach) Briq.
Sorbus torminalis (L.) Crantz. var. *torminalis* Euro-Sib
S. umbellata (Desf.) Fritsch var. *cretica* (Lindl.) Schn.

Rubiaceae
Asperula cymulosa (Post) Post Med. End
A. pontica Boiss. Euro-Sib
A. stricta Boiss. ssp. *monticola* Ehrend. Med. End
A. stricta Boiss. ssp. *stricta* Med.
Crucianella latifolia L. *Med.*
Cruciata laevipes Opiz Euro-Sib
C. taurica (Pallas ex Willd.) Ehrend. Ir-Tur
Galium album Miller ssp. *amani* Ehrend. et Schönb.-Tem.
G. aparine L.
G. incanum Sm. ssp. *elatius* (Boiss.) Ehrend. Ir-Tur
G. odoratum (L.) Scop. Euro-Sib
G. tenuissimum Bieb. ssp. *tenuissimum*
G. verum L. ssp. *verum* Euro-Sib
Putoria calabrica (L. fil.) DC. Med.
Rubia rotundifolia Banks & Sol. Med.
R. tenuifolia d. Urv. ssp. *brachypoda* (Boiss.) Ehrend. Med.
Sherardia arvensis L.

Salicaceae
Populus tremula L. Euro-Sib
Salix alba L. ssp. *micans* (Anderson) Rech. fil. Euro-Sib
S. pedicellata Desf. ssp. *pedicellata* Med.

Santalaceae
Osyris alba L. var. *serotinia* Griseb. Med.
Thesium bergeri Zucc. Med.

Scrophulariaceae
Anarrhinum orientale Bentham Ir-Tur
Bellardia trixago (L.) All.
Kickxia commutata (Bernh. ex Reichb.) Frit. ssp. *graeca* (Bor & Chamb.) R. Fernand.
Lesquereuxia syriaca Boiss. & Reuter Med.
Linaria chalepensis (L.) Miller var. *chalepensis* Med.
Misopates orontium (L.) Rafin.
Scrophularia scopolii (Hoppe ex) Pers. var. *scopolii*
S. xanthoglossa Boiss. Ir-Tur
Verbascum amanum Boiss. Med.
V. caesareum Boiss. Med. End
V. cedreti Boiss. Med.
V. cheiranthifolium Boiss. var. *asperilum* (Boiss.) Murb. End
V. galileum Boiss. Med.

V. linearilobium (Boiss.) Hub.-Mor. Med. End
V. lydium Med.
V. sinuatum L. var. *adenosephalum* Murb. Med.
Veronica arvensis L. Euro-Sib
V. cymbalaria Bodard Med.
V. leiocarpa Boiss. Med.
V. orientalis Boiss. Miller ssp. *nimordi* (Reichter ex Stapf.) M.A. Fischer End
V. persica Poiret
Wulfenia orientalis Boiss. Med.

Sinopteridaceae
Cheilanthes marantae (L.) Domin

Solanaceae
Atropa belladonna L. Euro-Sib
Datura innoxia Miller
Physalis alkekengi L.
Solanum dulcamara L. Euro-Sib
S. elatum Moench
S. nigrum L. ssp. *nigrum* Cosm.

Staphylaceae
Staphylea pinnata L.

Styracaceae
Styrax officinalis L.

Tamaricaceae
Tamarix smyriensis Bunge

Taxaceae
Taxus baccata L.

Thymelaeceae
Daphne oleoides Schreb. ssp. *kurdica* (Bornm.) Bornm.
D. oleoides Schreb. ssp. *oleoides* Shreb.
D. sericea Vahl Med.

Tiliaceae
Tilia argentea Desf. Euro-Sib

Typhaceae
Typha angustifolia L.

Ulmaceae
Ulmus glabra Hudson Euro-Sib

Urticaceae
Parietaria judaica L.
Urtica dioica L. Euro-Sib
U. urens L.

Valerianaceae
Valeriana alliariifolia Adams

Verbenaceae
Phyla nodiflora (L.) Greene
Verbena officinalis L.

Vitex agnus-castus L. Med.
Violaceae
Viola alba Besser ssp. *dehnardtii* (Ten.) Becker
V. parvula Tineo
V. shieana Becker
Vitaceae
Vitis sylvestris Gmelin
Zygophyllaceae

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Chapter 18
Interdependence of Biodiversity, Applied Ethnobotany, and Conservation in Higher Ecosystems of Northern Pakistan Under Fast Climatic Changes

Mushtaq Ahmad, Abida Bano, Muhammad Zafar, Shazia Sultana and Sofia Rashid

18.1 Introduction to Northern Pakistan

18.1.1 Biogeography of the Area

The northern Pakistan covers Gilgit–Baltistan, Azad Jammu and Kashmir, the upper region of Khyber Pakhtunkhwa, including Chitral, and some parts of the central and northern regions of Pakistan. The Himalayas, the Karakorum, and the Hindu Kush are famous mountain ranges and are one of the largest mountainous regions of the world which extends over an area of 132,700 km^2 and lies between 34°0′ to 36° 50′ N and 71° 12′–75° 0′ E (Hashmi and Shafiullah 2003) which give rise to a unique blend of habitats and biological communities (Sheikh 2000). The convergence of these magnificent ranges, at the confluence of Indus and Gilgit Rivers, creates a unique geographical feature on earth. The Karakoram Range covers the borders between Pakistan, India, and China, in the regions of Gilgit–Baltistan (Pakistan), Ladakh (India), and Xinjiang region (China). The range is about 500 km (311 mile) in length. The Himalayan range occupies, in Pakistan, the regions of Kashmir, Kaghan, Kohistan, Deosai, and Chilas. The Hindu Kush rises Southwest of Pamirs. Its third region lies in Pakistan and extends into Swat and Kohistan areas. On the East, it is separated from Karakoram by the mighty Indus River. Pakistan's forth major mountain range, the Suleiman range, emerges in the southwestern region of the country, mostly covering Baluchistan Province.

The greater Himalayan range runs west to east, from the Indus River valley in northern Pakistan to the Brahmaputra River valley in northern India and Tibet, forming an arc 2400 km long, which varies in width from 400 km in northern Pakistan to 150 km in the eastern Tibet. The Himalayas are bordered on the Northwest

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by the Karakoram and Hindu Kush ranges, on the north by the Tibetan Plateau, and on the south by the Indo-Gangetic Plain. The western Himalaya is dominated by Deosai plains situated at the average height of about 4114 m and covering an area more than 3000 km^2. This is so well known for its rich flora and fauna including summer flowers and endangered wildlife species. The three mountain ranges collectively contain about 25,000 species (about 10 % of world plant species), out of which around 10,000 are economically or medicinally useful (Pei 1992). Mountainous regions present a naturally conducive environment for the growth of medicinal plants. In the Himalayan ranges, at least 70 % of the medicinal plants and animals in the region consist of wild species, 70–80 % of the population depend on traditional medicines in health care (Pie and Manadhar 1987).

18.1.2 Geo-climate of Area

The mountaintops have arctic climate, while the valleys experience mild summer and cool winter (Khan 1995). The temperature in valleys ranges from extremes of almost 40 °C in summer to less than −10 °C in winter (Perkin 2003). The average rainfall is 1300 mm representing a subtropical-highland-type climate (Hamdani and Shah 2005). The flora and fauna of these ranges vary with climate, rainfall, altitude, and soils. Topography is rugged in the hills and foothills; however, in the plains it is regularly uniform. The valleys and foothills have been greatly dissected into depths and ridges because of water erosion over the time.

18.1.3 Floral Diversity

Owing to its peculiar geographical position, Pakistan harbors a great diversity of flora. More than 6000 vascular plant species occur in this region (Stewart 1972), out of which 5600 species have been described to date in the flora of Pakistan, representing 22 families and about 150 genera (Nasir and Ali 1970–95). Among the lower plants, there are at least 189 pteridophytes (ferns and their allies), of which 153 are Sino-Himalayan elements and 36 Euro-Siberian. However, algae, liverworts, mosses, and lichens are poorly known. About 87 genera and 3383 species of fungi have been reported from Pakistan (Mirza and Qureshi 1978). About 80 % of endemic flowering plants are confined to the northern and western mountains of Pakistan. Families with more than 20 recorded endemics are Leguminoseae (57), Asteraceae (50), Apiaceae (34), Poaceae (32), and Brassicaceae (21). The genus *Astragalus* contains 37, the largest number of endemics (Ali 1978; Ali and Qaiser 1986).

18.1.4 Wildlife Biodiversity

The northern areas harbor many species of wildlife due to great floral diversity and variety of habitats. Kashmir grey langur, black bear, brown bear, common leopard, leopard cat, Himalayan ibex, markhor, and gray goral are some of the rare and threatened mammals found in the valleys. rhesus monkey, red fox, jackal, stone marten, yellow-throated marten, small Kashmir squirrel, giant red flying squirrel, Royle'spika, and Indian crested porcupine are commonly found in the valleys (Saddozai 1986).

18.1.5 Major Vegetation Biomes/Ecosystems

Most of the natural forest resources of Pakistan are concentrated in the mountainous regions of the north-covering Himalaya, Hindu Kush and Karakoram ranges, where more than 60 % of the country's natural forest resources are found. The rest of the forestry resource is distributed among the southwestern mountains of Baluchistan, plains of Punjab and Sindh, and the coastal areas of Arabian Sea in the south. Ecologically, nine broad forest types are found in Pakistan (Champion et al. 1965).

1. *Alpine tundra*
   This biome is predicted in humid areas that have abundant precipitation to support tree growth. It covers fairly flat ground at an altitude of more than 3660 m, which is covered by snow for 5–6 m in a year. Naturally occurring grasses in these alpine pastures or meadows are *Festuca, Poa, Lolium, Eragrostis, Danthonia,* and *Phleum,* as well as many forbes, such as *Primula, Aremons, Fritillaria,* and *Gentiana*sp. The grasses and forbes are highly nutritious and are extensively and heavily grazed during summer months by herds of goats, sheep, and horses and are thus being degraded at a fast rate. Wooded tundra also has subalpine mixed forests of *Salix, Lonicera, Berberis, Conoteaster, Juniperus, Rhododendron,* and *Ephedra*.
2. *Cold conifer/mixed woodland*
   This biome contains both the boreal conifer forest/woodland and the boreal deciduous forest/woodland biomes of Prentice et al. (1992) that are dominated by cool temperate conifers *Abiesspectablis, Pinuswallichiana,* and *Juniperusrecurva,* and evergreen broad-leaved trees *Betulautilis, Salix, Vibernum,* and *Rhododendronanthopogon* sporadic single trees, in groups, or in irregular dense stands. They have a humid maritime climate with winter temperature of −2 to –15 °C or even colder (>−60 °C) with too little precipitation.
3. *Cold conifer/mixed forest*
   This biome also corresponds to the subalpine forest type and consists of dense forests with species composition, characteristics, and occurrence which are the

same as for the cold conifer/mixed woodland biome. The trees have a moderate rate of growth in this biome.

4. *Temperate conifer/mixed forest*
   These are extensive coniferous forests that are similar to north temperate forests in Europe and North America, having commonly, more or less, pure crops of two species, and the mixtures of blue pine *Pinuswallichiana* and Deodar *Cedrusdeodara*. Winter temperatures are $>-4\,°C$ within an altitudnal range of 1800–3660 m on moderate-to-steep slopes. Other species are fir *Abiesspectabilis,* spruce *Piceasmithiana, Pinusgeradiana, Juniperusexcelsa, Quercusdilatata, Q. semicarpifolia, Populusciliata,* and *Aesculusindica*. The wood of all species is highly valued as timber. In addition, medicinal plants, mushrooms, and fodder are collected in the forests.
5. *Warm conifer/mixed forest*
   This biome is dominated mostly by warm temperature evergreen conifer trees of chir pine *Pinusroxburghii* in regions with mean coldest month temperatures of 5–15 °C and with rainfall sufficient to meet more than 65 % of the moisture requirement between 1000 and 1800 m elevation.
6. *Xerophytic wood/scrub*
   These are low forests of branchy, thorny, evergreen trees, and shrubs. Their major climatic descriptor is a long dry season tempered in more northerly parts by winter and spring precipitation and to the south by a summer monsoon of variable incidence. The dominant species are *Oleaferugiea, Acacia modesta,* and *Dedonaeaviscosa*.
7. *Grassland/arid woodland*
   This biome consists of tropical plains and has *Prosopis cineraria, Salvadora oleoides, Acacia senegal, Calligonum polygonoides, Zizyphus mauritiana*, and *Tamarix troupe* along with a number of grasses, such as *Eulaliopsis binata, Themedia anathera, Cenchrus celliaris,* and so forth.
8. *Steppe/arid shrubland*
   This biome is somewhat similar to the xerophytic wood/scrub biome. *Olea ferugniea, Pistacia* spp., *Fraxinus xanthoxyloides, Dephne mucronata, Astragalus stockii, Helliotropium* sp., and *Artemisia* spp. are found in it.
9. *Deserts*
   This is the largest type and covers most of the Indus plain, including the major deserts of Thar, Thal, and Cholistan; in total, over 11 million hectares in Pakistan. Rainfall is less than 500 mm. These deserts have been converted into agricultural land and 103,000-ha tree plantations wherever irrigation water is available. Riverine forests receiving floodwater cover 173,000 ha, and mangroves along the sea coast cover 207,000 ha. The rest of the area is used for grazing. Scattered trees and shrubs are found in it. It is similar in plant composition to the grassland/arid woodland biome.

18.2 Ethnobotanical Exploration in Northern Pakistan

18.2.1 Linkage of Traditional Knowledge with Conservation

Indigenous people and local communities in this region have since long resisted the use of art and crafts, traditional symbols, and designs; the use or modification of traditional songs; the patenting of traditional uses of medicinal plants; and the copyrighting and distribution of traditional stories. Certain communities have also sought to ensure that their traditional knowledge (TK) is used equitably—according to restrictions set by their traditions, or requiring benefit sharing for its use. In the recent years, the role of indigenous knowledge in a range of sectors is being talked about. It includes intercropping techniques, pest control, crop diversity, and seed varieties in agriculture; plant varieties and fish breeding techniques in biology; traditional medicine in human healthcare; soil conservation, irrigation, and water conservation in natural resource management; and oral traditions and local languages in education. The realization of indigenous knowledge contribution to these sectors has led to an increasing interest in it by academicians, and policymakers alike. Many government and nongovernmental organizations, as well as international organizations such as the World Bank, International Labor Office, United Nations Educational, Scientific and Cultural Organization (UNESCO), and Food and Agricultural Organization (FAO) are now appreciating the role indigenous knowledge can play in achieving sustainable development in a country. This interest is also apparent in the policies and programs of various countries.

18.2.2 Loss of TK in Northern Pakistan

In the Himalayan region, medicinal plants are used extensively for a very long time. In a recent survey conducted by World Health Organization (WHO), traditional healers treat 65 % patients in Sri Lanka, 60 % in Indonesia, 75 % in Nepal, 85 % in Myanmar, 80 % in India, and 90 % in Bangladesh. Pakistan has 60 % of its population, especially in villages, that receive their health care from traditional practitioners (Haq and Hussain 1995). In early 1950, up to 84 % of Pakistani population was dependent on traditional medicines for all or most of their medicinal use (Hocking 1958). In Pakistan, knowledge of medicinal plants is rapidly disappearing. Every year, the sum total of human knowledge about the types, distribution, ecology, methods of management, and methods of extracting the useful properties of medicinal plants is declining rapidly—a continuation of a process of loss of local cultural diversity that has been underway for hundreds of years. There has, of course, been a great growth in scientific information about medicinal plants in recent decades, but in many ways this has proved poor compensation, because such information is accessible, in practice, only to a very few people and, anyway, rather little of it is relevant to problems of management and utilization, as encountered in the field. Among those liable to suffer most from loss of indigenous knowledge are those who live in harsh places, such as mountain ranges, and who have high degrees of dependency on their local natural environments. The cultures and economies of such people must be closely adapted to the intricacies of their local environments, if they are to prosper. Knowledge of the natural world is typically a very important part of the knowledge of rural people following more traditional lifeways. Further, medicinal plants tend to figure prominently in these galaxies. It is, therefore, not surprising that the revitalization of traditional systems of medicine can be high on the agendas of those promoting local and indigenous cultures, a political trend in many parts of the world.

18.2.3 Threats to Traditional Knowledge

Traditional and folklore medicine are commonly used from generation to generation in domestic recipes and community practices. Developed countries are also turning to the use of herbal drugs and remedies. Mostly, the elder women are keeping this knowledge which is a rich heritage in the combined family system of northern Pakistan. This knowledge is going to diminish day by day with the deterioration of cultural norms. The way elders transmit TK to their younger is not always assured. It is high time to document this source of knowledge for future generations. Although some indigenous knowledge is lost naturally as practices get modified or are left unused for long time periods, the current rate of loss can be attributed to modernization and cultural homogenization, the current educational systems that believe macro-level problems can only be addressed through the global knowledge pool, and the slow growth of institutions supporting grassroots innovations. With rapid population growth, in-migration, and government relocation schemes (in the case of large development projects), standards of living is often deteriorated. As poverty augments, short-term economic gains are chosen over environmental-friendly local practices. The introduction of monocropping patterns in agriculture and forestry results in a loss in biodiversity, thus leading to a decline in indigenous knowledge. Deforestation leads to the disappearance of several precious, yet unknown, medicinal plants, and, as a result, the knowledge associated with those plants also declines. A lot of TK is also being lost because of the communication gap, since neither children nor adults spend as much time in their communities. Because indigenous knowledge is generally transmitted orally, it is susceptible to change, particularly when people move to new regions, or when people's lifestyles tend to be different from that of their ancestors.

International attention has shifted to intellectual property laws to preserve and promote TK in the past years. The Convention on Biological Diversity of 1992 acknowledged the contribution TK can make in protecting species, ecosystems, and landscapes, and, therefore, included laws pertaining to its access and use. Experience has proved that developmental activities that tend to ignore local technologies; local knowledge systems, and those which fail to formulate policies without a concern for local environment generally fail to achieve the desired outcomes. Although the TK of the Indigenous Peoples has been found to be very useful and effective, it has still been neglected by the world. There are many threats like environment, urbanization, globalization, climate change, global warming, etc. Pakistan has a very rich history of plants use in the rural areas where 80 % of the population lives. More than 95 % of the rural people of northern Pakistan depend upon folk medicine for their primary health care. The reason for this frequent use of traditional medicines is strong association of people with the local flora and the TK regarding plant use, economic and easy availability of the medicinal plants, poor access to allopathic drugs, and lower economic profile of the communities.

18.3 Threats to Biodiversity in Northern Pakistan

18.3.1 Importance of Biodiversity

The role of biodiversity is crucial in the maintenance of healthy environment and survival of mankind. Biodiversity provides free-of-charge services worth billions of dollars to mankind in the form of clean water, pure air, pollination, soil formation and protection, crop–pest control and provisions of food, fuel, fibers, and drugs. Biodiversity plays an important role in the prevention of floods, landslides, avalanches, soil erosion, wind erosion, siltation of dams, and water reservoirs. Thus, biodiversity is saving billions of rupees each year which would have been otherwise spent to control such calamities (Shah 2008). Biodiversity not only controls the global warming which adversely affects crop pattern throughout the world resulting in famine and hunger but also plays a crucial role to control and check rising of sea level which is threatening many European countries. Conservation of biodiversity is crucial to the sustainability of sectors as diverse as energy, agriculture, forestry, fisheries, wild life, industry, health, tourism, commerce, irrigation, and power (Table 18.1).

Pakistan harbors rich variety of flora and fauna which is mainly due to great variations in its temperature, rainfall, and altitude. Pakistan with an area of less than one million square kilometers consisting of desolate hot and cold deserts, forested valleys, and snow-bound mountains and deserts, rivers and lakes, and estuaries and oceans. These variations rise to the support of 188 species of mammals, 668 species of birds, 177 species of reptiles, and 6000 species of plants. Some species have very restricted ranges of their occurrence in the nature and are endemic to Pakistan (Shah 2008).

Table 18.1 Biodiversity facts and figure of northern Pakistan

Taxon	[a]Reported for Pakistan	Estimated for northern areas	Endemic to northern areas
Mammals	174	54	2
Birds	668	230	–
Reptiles/amphibians	177/22	23/6	4/2
Freshwater fish	198	20	4
Insects	>5000	?	–
Plants	>5700	?	

[a] Reported in Biodiversity Action Plan for Pakistan (2010)

18.3.2 Impact of Climatic Changes on Biodiversity

Climate change is having widespread impacts across multiple scales of biodiversity including genus, species, communities, and ecosystems (Parmesan 2006; Bellard et al. 2012). Biological responses to climate change vary widely among species and populations; some responses are positive, leading to increased growth rates or range expansions, while others are negative, resulting in localized or widespread declines (Montoya and Raffaelli 2010). Climate change is causing many species to shift their geographical ranges, distributions, and phenologies at faster rates than were previously thought; however, these rates are not uniform across species. Biodiversity is fundamental to ecosystem structure and function, and underpins the broad spectrum of goods and services that humans derive from natural systems (Naeem 2009; Mace et al. 2012). Declines or loss of any aspect of biodiversity can have direct or indirect impacts on ecosystem function, persistence, and services (Hooperet al. 2005). Plants are major regulators of global climate and are the keystone of the carbon cycle. Loss of plant species will disproportionally affect the rural poor where a large majority of whom rely on wild natural resources for medicinal purpose and daily uses. Climate change is altering the abiotic conditions that influence biological systems, and processes biological responses to climate change depend on a number of factors, including the rate, magnitude, and character of the change, ecological sensitivity, and adaptive capacity to environmental change. The combination of these factors is affecting all levels of biodiversity, such that the distribution, organization, and interactions among biota are shifting over spatial and temporal scales (Walther 2010).

There is growing consensus in the scientific community that climate change is occurring. There is unequivocal evidence that climate change is occurring and having impacts on biodiversity—the Intergovernmental Panel on Climate Change (IPCC 2007). While the absolute magnitudes of predicted changes such as these are uncertain, there is a high degree of confidence in the direction of changes, and in the recognition that climate change effects will persist for many centuries. The United Nations IPCC has concluded that the global atmosphere is warming, noting that the average global surface temperature has increased by nearly 1 °C over the past century and is likely to rise by another 1.4–5.8 °C over the next century (IPCC 2001). Atmospheric warming affects other aspects of the climate system: The pressure and composition of the atmosphere; the temperature of surface air, land, water, and ice; the water content of air, clouds, snow, and ice; wind and ocean currents; ocean temperature, density, and salinity; and physical processes such as precipitation and evaporation.

18.3.3 Major Threats to Biodiversity

According to forests, scrubs, and planted trees on farmlands cover only 4.2 million hectares, or 4.8 % of the country. If plantation and scrub forests are excluded, the coverage falls to 2.4 million hectares (2.7 %). Woody biomass is declining at the rate of 4–6 % per year and with consumption expected to grow in line with population growth (3 % per year); this biomass could be totally consumed within the next 10 years. The list issued by the International Union for Conservation of Nature (IUCN; 1998) contained 37 species and 14 subspecies of internationally threatened or near-threatened mammals occurring in Pakistan. There are further 25 internationally threatened bird and 10 reptile species.

The magnitude and distribution of species that exist today is a product of more than 3.5 billion years of evolution, involving speciation, migration, extinction, and, more recently, and human influences. Estimates of the total number of species in existence range from 7 to 20 million, but perhaps the current best working estimate is between 13 and 14 million species (IUCN Red List (1997). Information based on taxonomic literature suggests that only 1.75 million of the species that exist have been described. Floristic diversity of the western Himalaya is declining at an alarming rate. The various threats posed to the plants of the area have been identified.

1. *Threat of habitat loss*
   Almost everywhere in the world, humans have a strong impact on the natural habitats of plants and animals—in high alpine regions as well as on coastal lines, in deserts as much as in rain forests. The forest are cut down to make space for arable land or to satisfy the industry's need for wood, and, thus, eventually our habitat, are fundamentally affected or destroyed. Of course, these changes have an impact on medicinal plants, too. Habitat destruction can affect medicinal plants in many different ways. The most direct effect is the immediate extinction of species in a certain region by destruction of the ecosystem. Obvious examples are the increasing number of "slash and burn" clearings. The soil, deprived of its natural vegetation, is prone to uncontrollable erosion, particularly if it is not allowed to regenerate back into forest. Then vegetation previously native to a certain area disappears irreversibly, and with it the medicinal plants. Inappropriate harvesting can cause a similar form of habitat destruction.

2. *Exploitation of the wild stock of medicinal plants*
   Traditionally, medicinal herbs have been collected and used locally. Together with growing urbanization and the extension of trade relations accompanying urbanization, medicinal plants have entered trade on a larger scale. Medicinal plants have become a commodity and obtained an isolated value that was no longer connected to their original function. The escalation in trade volumes may also be partly due to people longing (especially in industrialized nations) for a "natural" healing through natural agents. This development has led to an exploitation of the wild stock of some medicinal plant species. This reckless overexploitation is motivated by the benefits of a short-term profit to be gained by exploiting the resource and neglects all considerations of sustainability. Over-exploitation in combination with other factors has brought plant species such as *Podophyllum hexandrum, Valeriana jatamansi, Geranium wallichianum, Bergenia ciliata, Primula denticulata, and Saussurea lappa* to the verge of extinction in their native areas.
3. *Genetic erosion and changes*
   In nature, genetic changes (mutations) occur constantly; they are the basis of the evolutionary process and species development. New species develop if mutations or a series of mutations lead to the separation of mutants and nonmutants and subsequent formation of groups, subpopulations, or populations. This is a constant and value-neutral evolutionary process. Humans can also induce genetic changes by mutations. Contrary to the natural process, artificial mutations usually have a certain purpose. Induced genetic changes in medicinal plants through cultivation and development of varieties often are intended to intensify the concentration of certain compounds. The changes and the subsequent adaptation to the newly created conditions—unlike in nature—take place very quickly, often within a few years. The desired results are achieved in the beginning, but the equilibrium of the plants is often disturbed.

18.3.4 Human: A Causal Agent/ Major Threat Toplant Diversity

The following human activities can be enumerated as the principal threats to conservation of biodiversity:

1. *Grass cutting*
   The effects of grass cutting are also considerable. Usually, people cut grass and store it, to be used in winter to feed cattle. While cutting grass, seedlings are uprooted or damaged. Similarly, the eggs or sometimes young babies of pheasants are killed. Similarly, some of pheasant species are migrating due to inadequate protection. The intensive grass cutting has also effects on herbal layer and the composition is greatly disturbed.
2. *Extensive collection of medicinal plants/herbs*
   Commercial gatherers of medicinal plant material, whether for national or international trade are poor people whose main aim is earning money, and not

resource management. A major proportion of the non-wood forests products, especially the medicinal and aromatic herbs collected from the wild, is meant for export. Hence, the quantities of different forest products collected are mostly determined by the demand from abroad. As a consequence, raw materials are overharvested by the removal, for example, of mature plants, roots, tubers, and rhizomes, or by overpruning. As an outside interest dictates the price and quality of raw materials extracted, a major part of local ecosystem has suffered irreversible loss. The most detrimental effects on the herbal layer of young plants, birds, small animals and other vegetation are caused due to mushroom *Morchella esculanta* collection. This mushroom is very rare and highly nutritious and costly. This is usually collected in the breeding season of most of bird's species, which disturbs their breeding and destruction of their nests. Due to tampering of soil, heavy soil erosion is resulted. The valuable herbs and medicinal plants, collected are *Viola odorata, Podophyllum hexandrum, Geranium wallichianum, and Valeriana jatamansi* and is the major source of income for the locals especially for women. However, due to unsafe collection methodology and high collection rate the natural succession of these species is greatly disturbed and both production and species population is greatly hampered.

3. *Invasive species*
   Introduced or alien invasive species can have a significant negative impact on biodiversity. The effect of exotic species on the native fauna and flora of Pakistan has not been well documented. In attempts to meet the increasing demands of a rapidly growing human population, fast growing exotics have been introduced to alleviate shortage in timber, fodder, and fuel wood. Prominent tree species include Eucalyptus species, hybrid *Populus,* and *Robinia* species planted on farmlands and irrigated plantations. While these species do not appear to have threatened indigenous vegetation so far, the introduction of *Broussonetia papayrifera, Robinia pseudacacia, Ailanthus altissima, Cedrellatoona,* and *Eucalyptus* species in the subtropical Chir pine zone may pose threat to natural habitats in the future.
4. *Natural hazards*
   The area is susceptible to landslides which results in destruction of forests. The situation became worse on 8 October 2006 when an earthquake of 7.8 jolted northern Pakistan in which thousands of people died, their properties were damaged, and fauna and flora of the area were also badly affected. Although it was a natural calamity, but most of the deaths occurred due to landslides, because the mountains were naked, due to the ruthless cutting of the forests, so human beings themselves were responsible for this loss. Heavy snowfall and torrential rains which result in flood and landslides are of common occurrence. The occurrence of floods is common phenomena in hilly areas. In the near past, these have destroyed agricultural fields, houses, irrigation channels, and communication lines in addition to loss of human life. Avalanches and landslides are frequent in the area which causes considerable destruction to the forest. Avalanches are very common during winter season, as moving avalanches kills herbs, shrubs, and even trees. Landslides cause decrease in forest cover. A considerable damage is

caused to the upper parts of the forests on account of snow slides. The frost of severe intensity occurs in winter that kills the young plants and the growing parts of the mature ones. The hillsides are subject to erosion as a result of excessive grazing, browsing, and lopping in addition to clearing of forest land for cultivation. Besides the faulty practices of cultivation, the erosion hazard becomes more dangerous on steep slopes.

5. *Extensive trade of medicinal plant resources*
   A survey of the naturally available plant wealth of Pakistan shows that medicinal plant grow in abundance in Hazara, Malakand, Kurram agency, Murree hills, Azad Jammu and Kashmir, Gilgit–Baltistan and Balochistan, or are cultivated farmlands in Punjab, Sindh, Baluchistan, North-West Frontier Province (NWFP), and Kashmir. According to the surveys carried out by the Pakistan Forest Institute (1989), 500 t of medicinal plant are produced in Hazara and Malakand, 16 t in Murree hills, 38 t in Azad Kashmir, and about 24 t in the northern areas annually. These plants are collected from the wild, dried and processed, and sold in the local market or exported to other countries. According to a survey, crude medicinal plant materials worth more than Rs. 150 million (US$ 2.3 million) per year are used in Pakistan. Most of these plants are obtained from the wild. Pakistan exports large quantities of crude plants at very cheap prices in the international market (worth US$ 6 million). In the entire business chain, gatherers receive the least money and are forced to collect more and more plant material to survive. It is an experience shared by most other resource-rich developing countries. Pakistan obtains more than 80 % of its medicaments from higher plants. Trade of crude drugs is very erratic. Prices fluctuate greatly due to variations in external and internal demands within the country. The actual supply/demand of herbs and medicinal plants is in the range of 20,000 t per annum. As regard the availability of medicinal plants collected, 37 % are available in the month of August, 26 % in March and April, 11 % in December and January, 17 % in September and November, while 9 % of the medicinal plants are available throughout the year.
6. *Wild vegetables*
   Fifty-five plants reported from the area are consumed as vegetables. Bush food (Falconer 1992) in its broader sense can be used for all the edible wild plants and animals and their products like waxes honey, etc. The plants used in the form of wild fruits, potherbs, spices, cash plants, and dry fruits species supply a fraction of the food requirements of the people. The soil flourish a variety of culinary herbs among which the young fronds of male ferns locally called "Coonje" and shoots of *Medicago* species and leaves of *Rumex nepalensis, Nasturtium,* and flowers of *Bauhinia variegata* are used by most of the families as vegetable. The delicious potherb, which we observed, is *Phytolacca latbenia* whose fruits are also boiled in water and used locally as ink. A total of 56 edible mushrooms are reported from Pakistan including 3 from Sindh, 4 from Balochistan, 5 from Punjab, and 44 from NWFP, Azad Kashmir and northern areas (Phillips and Hurst 1986). Most commonly collected mushrooms is (*Morchella esculenta*). This is one of the main minor forest products which local people collect to meet

their domestic nutritional needs and obtain additional income by selling these in the market. Households involved in collection of mushrooms can increase their incomes by adopting techniques of growing, processing, and preservation. At present, people do not have any idea about its in-house farming for sustained supply. People need to get training in growing, processing, and preservation of mushroom to increase their income.

7. *Ownership disputes*
   Another hurdle to protect the forests and reforestation are ownership disputes among the owners (landlords) and local farmers. Planting of trees for fodder or firewood is constrained by poorly defined regimes of land tenure and resource ownership, and a disparity in influence between those who are most directly concerned with wild plant resources (women) and those who make official decisions (men).
8. *Fuel wood pressure on forest resources*

One of the most serious problems in the developing world is the shortage of fuel wood and a similar situation prevails in Pakistan. As the National Conservation Strategy (NCS) points out, Pakistan is an energy-poor country. Rural dwellers have little access to commercial energy recourses and are often forced to rely upon the nations dwindling forest recourses and other biomass for fuel for cooking and heating.

18.3.5 Major Causes of Deforestation

The forests of area are cut ruthlessly, the impacts of which are visible in the form of more and frequent flash floods, loss of soil, reduced productivity of agricultural land, and reduction in freshwater sources. Some of the reasons for the decreasing forest cover in the area are:

1. *Encroachments for cultivated lands*
   People's aptitude for getting cultivation land has increased the trend of cutting trees in the recent years. The practice is very common as cultivated patches are seen everywhere in the forests of the valley. In these newly built farms, the people cultivate potatoes or other cash crops of the area. People were seen working in the fields in the forests surrounding the villages. This method of making new land patches through deforestation is very dangerous and if not checked will convert the precious forests into cultivated fields.
2. *Illicit felling and lopping of trees for fodder*
   A good number of poles and trees of coniferous species are cut every year without any restriction for making fences around the agriculture fields and the home-gardens to protect their vegetable, crops, and fruit trees from the cattle. Broad-leaved trees are also cut and lopped for fodder and firewood. The shortage of fodder and other feeding material has resulted in heavy lopping of trees for fodder. Heavy lopping of trees for fodder has manifold effects. *Quercus incana*

and *Aesculus indica* are extensively used as green fodder during winter and locally *Quercus incana* is on the verge of extinction. Similarly, other tree species like *Aesculus indica, Acer* species *Prunus cornuta,* and *Populus ciliata* are heavily pruned during the nesting periods of birds which badly effects breeding. Majority of herbivorous animals are dependent on the trees for fodder during the entire year. The growth of fodder trees is also retarded due to heavy lopping and repeated lopping results in different diseases and ultimate death of the tree. Fir trees are pruned to an extent that young crop is almost with the retarded growth. Himalayan yew *Taxus wallichiana* has also been badly lopped as fodder and is critically endangered.

3. *Over grazing and browsing*
   The forests have been considerably damaged on account of heavy grazing and browsing and the process is still going on unchecked. The damage is more visible near the habitations, water points, and rest places of cattle. The grazers have constructed their huts inside the forest. They graze and browse their animals till it becomes difficult for them to stay due to cold. Some nomadic Gujars from other areas visit these areas along with their goats and cause damage to the vegetative cover.
4. *Forest resources and their usage*
   Being unaware of the importance of conservation of forests, the local population luxuriantly uses resources thereof in an unsustainable way. In the winter season, consumption of wood increases multifold due to which huge amounts of wood of precious trees like *Abies pindrow, Cedrus deodara, Picea smithiana,* and*Quercus dilatata* are used for burning purpose. *Pinus wallichiana* trees near the villages are invariably damaged for the extraction of torch wood. The trees get weaker at the base and are blown over by wind. The wooden planks of *Cedrus deodara* are used for making water channels through which water is brought from far flung streams in order to run turbines for the production of energy.
5. *Timber and construction material*
   The most preferred species for timber are *Cedrus deodara, Pinus wallichiana, Pinus roxburghii, Parrotiopsis, Olea, Juglans, Plectranthus rugosus, Indigofera* species, *Sophora* species, and*Quercus* species. In general, houses consume a lot of timber wood. Such lavish use of timber originated probably from early times when forests covered all the area and were cleared by early settlers to get land for farming. At present, most of the forests in surrounding villages have been severely depleted through felling trees indiscriminately, usually deodar poles for constructional purpose. Wood sleepers are loaded in the trucks within miscellaneous items and are smuggled to various parts of the country.
6. *Forest fires*
   There is no record of the extent and damage on account of fires but it appears that there have been frequent fires in some of the localities. The causes of fire are either rivalry in order to harass and damage the property of other tribes or burning wood, etc., for cooking and heating by carefree people. Fires are, however, a potential threat to the forest flora of the valley.

7. *Population explosion*
   In the last couple of decades, the population of the valley has increased multifold. During the winter season, the migration of local people from their homes to the low-lying areas decreases, which increases demands on forest resources. Similarly people from far-flung areas are continuously purchasing lands in the valley to build homes so that they could spend summer season over there. The increase in population has accordingly resulted in the deforestation with an increased rate.
8. *Agricultural appliances*
   The major occupation of local community is agriculture, and different types of traditional agriculture appliances are needed to work in the fields. These appliances are either totally made of wood, e.g., plough or handles are made of wood, e.g., axes and sickle. Thirty-seven species are utilized in making agricultural tools, which is 5 % of the total reported species from the area. Ploughs, wheels, sticks, carts, sickle handles, hoe handles, pullies, knife handles, and axils are made of locally available hard and soft wood. They include *Abies pindrow, Pinus wallichiana, Quercus dilatata, Quercus incana, and Olea ferruginea*. The community is dependent on agriculture and livestock and most of cultivated fields are closer to the alpine pastures or meadows where animals graze. Therefore, the farmers have to take special measures to protect their valuable crops. For this purpose, they use spine-bearing plants around cultivated fields or make fences. Fences and hedges are made up of 19 species. They generally consist of the species, which are bushy and spiny. Such species consist of *Acacia modesta, Berberis lycium, Rosa moschata, Rubus fruiticosus,* and *Ziziphus sativa*. These plants are cultivated on the margins of the fields and form a permanent fencing or branches of these plants are fixed in mud on the margins or it performs as temporary fencing—wood pieces are also used to make permanent fences.

18.4 Conservation Strategies

18.4.1 Biodiversity Conservation in Pakistan: An Overview

Chaudhri and Qureshi (1991) indicated that as many as 709 species of the vascular plants of Pakistan, constituting about one tenth of the vascular flora, are in danger of being gradually wiped out or exterminated altogether. Martin (1995) reported that the chief threat to the trees and shrubs of the Sulaiman Ranges is the fuel shortage in the mountain, whereby, due to long and severe winters, fuel is used for heating purpose.

Shinwari et al (2000) worked out the conservation status of medicinal plants in Pakistani Hindu-Kush Himalayas. They estimated that more than 10 % of the flora is threatened and 12 % is used medicinally. They mentioned that the total number of medicinal plants of the district Swat ranged from 55 to 345 species. They also reported that the natural resource base in the Hindu-Kush Himalayas is deteriorating more rapidly than in any other global region. Shinwari (1996) reported that the natural resource base in the Hindu-Kush Himalayas is deteriorating more rapidly than many other global ecosystems. Various threats which are posed to conservation of this region include fuel shortage, construction of roads and buildings, overgrazing for forage, wood cutting for timber, medicine, furniture, charcoal, etc. Shinwari and Khan (1998) investigated and listed the fuelwood species of Margalla Hills National Park, Islamabad. Thirty-five species were used among which *Acacia modesta, A. nilotica, Buxus papillosa,* and*Dodonaea viscosa* were under high fuelwood pressure. Shinwari and Khan (1999) recorded the local uses of plants of the Margalla Hills and their conservation status. They stated that *Asparagus adescendens, Berberis lyceum,* and *Viola canescens* are vulnerable to harvesting. *Acacia modesta, A. nilotica, Buxus papillosa,* and *Dodonaea viscosa* are under fuelwood pressure. *Grewia optiva* emerges as the most sustainable species. The Astore area, Gilgit, was analyzed for the conservation of plant biodiversity by Shinwari and Gilani (2003) and found that 5 species out of 34 medicinal plants were endangered, 18 vulnerable, and 19 rare. Khan et al. (1996) studied the impact of fuel shortage on conservation of biodiversity of the Hindu-Kush-Himalayan mountainous region. They mentioned that the northern area of Pakistan is endowed with immense natural resources which are being rapidly unchecked and uncontrolled. The most serious crisis to the loss of biodiversity is due to fuel shortage, which mainly comes from firewood species. Khan et al. (1996) surveyed ten strategic villages around Deosai plains through Rapid Rural Appraisal (RRA) in order to get people's perception about the floral and faunal significance of Deosai plains. They found that people are consuming the natural resources of Deosai for their short-term gains without knowing its long-term repercussions. They suggested that for sustainable and long-term conservation of alpine natural resources, there is a need to actively involve the acquiescence of local people in evaluation, planning, implementation, and monitoring processes, as they are the best judges of the area. Rehman and Ghafoor (2000) studied the human influence on the natural resources of Mount Elum, Swat. Analysis of the socio-economic profile revealed that land tenure and ownership conflicts were the basic causes of the depletion of natural resources and ecological degradation.

18.4.2 Protection and Conservation Measures

The natural resources of the area are deteriorating rapidly. Serious threats to the flora are the fuel shortages for the rapidly increasing population. Terracing of land for agricultural purposes, indiscriminate deforestation for economic reasons, and overgrazing are the other threats having resulted in a severe biotic stress. It is an appropriate time to check the existing position of the flora and to work for remedial measures for protection and conservation of the dying beauty of the area.

1. *Awareness campaign and incentives*
   To know the importance of the indigenous flora and forests for the existing ecosystem, awareness campaigns are required to be launched in the area. For successful protection and conservation measures, extending proper incentives for the local population are one of the essential prerequisites. Further, to make the area free of corruption, the locals are required to be given their free royalties. Like other forest areas in the district, some of the local elders, called Maliks, are denying due shares in royalty to common villagers of the valley.
2. *Protection against browsing/grazing*
   Being threatening to the ecosystem, the browsing and grazing rates are required to be checked properly. Permanent closure of the forests against browsing and grazing, would neither be economical nor politically practicable. The envisaged means for protection are the following:
   Those forests which are already on the verge of collapse due to overgrazing and extensive browsing are required to be banned for the purpose. For the same, proper fencing of the forest is made through barbed wire, waste wood, and branches. This can be made through consultation with the local population. The more the local people involved in the implementation, the greater will be the achievements.
3. *Protection against encroachment and illicit tree felling*
   There should be complete ban on illicit cutting of trees, encroachments, and the restoration of degraded land/ forests through establishment of community-protected areas.
4. *Soil conservation*
   There should be proper tree plantations and pasture management activities in the area. Since this is not possible without the community participation, the local population is required to be properly educated and taken into confidence for a thorough change in the area. All conservation measures are possible only when the main actors of the conservation strategies are involved fully in the process.
5. *Active government and nongovernmental organizations (NGO's) participation*
   Proper education and training are the most important prerequisites for the conservation and sustainability. The government (Forest Department) and NGO's are required to properly educate the people living in the area. This will also aid to other conservation efforts.

18.4.3 Conservation of Floristic Diversity

One of the deepest concerns in plant conservation is the large number of species under threat of extinction. Preserving the extinction of species is a top-conservation priority, because, once lost, species are gone forever. Attention is required to the management and protection of various ecosystems including in situ and ex situ conservation of species. The following conservation effort was made to conserve the floristic diversity:

1. *Ex situ conservation*
Propagation and maintenance of different species under partially or completely controlled conditions is known as ex situ conservation. This is a method of conservation of species outside their natural habitats. It involves preservation of endangered plants in botanic gardens, gene banks, laboratories, or nurseries, so that the genetic characteristics are maintained in live organisms. Ex situ conservation approach is useful and necessary when the population of a species is likely to be extinct or it has got high education value or it is facing a high pressure in wild habitat or it is to be propagated largely for commercial, recreational, aesthetic, or other purposes. Trials were successfully carried out with the collaboration of local farmers on medicinal plants *Achillea millefolium, Atropa acuminata, Geranium wallichianum, Lavetera Cashmirana, Podophyllum hexandrum,* and*Paeonia emodi*. Seeds of important endangered tree species e.g, *Betula utilus, Prunus cornuta, Fraxinus excelsior, Acer caesium, Taxus wallichian, and Ulmus wallichiana* were collected, and nursery was raised with the collaboration of forest department. Seeds of endangered plants were collected from the wild and stored in the gene bank of Plant Genetic Resource Institute (PGRI), National Agricultural Research Center (NARC), Islamabad, Pakistan, as an ex situ conservation effort. Furthermore, nurseries of some important endangered plants were also raised with the collaboration of the forest department. The plantlets were distributed among the local community. Public awareness campaign was also launched by delivering lectures in the local schools. Religious leaders of the community were also consulted to deliver sermons regarding the importance of plants and teachings of Islam about the protection of environment and conservation of natural resources. This was an in situ conservation effort. Plantlets were distributed among the local community for plantation in their fields and pastures. The community was also informed about the recent situation of different plant resources of the area and conservation status of different endangered plant species.
2. *In situ conservation*
In situ conservation is the best method for conserving genetic and plant resources but execution is not easy due to population pressure and resource constrains. During field research, an effort was made to inform and educate the local community regarding conservation and sustainable utilization of plants. The areas need much effort from the government and the NGOs' side, as people are very poor and illiterate. A similar artificial regeneration of *Dioscorea deltoidea, Atropa acuminata, Valeriana jatamansi, Mentha arvensis, Rheum emodi, Colchicum luteum, Digitalis pupurea, Podophyllum hexandrum, Pimpinella anisum, Catharanthus roseus,* and *Saussure alappa* has also been tested, under controlled environmental conditions, and by the application of various agrochemical, in the hill forest of NWFP (Khan et al. 1996). Most of the conservationists agree that in situ conservation is preferable as far as it is possible. There is a need to preserve habitats with their whole-diversity organisms. If habitats are managed, then plant species will manage themselves. This is probably found true in many cases. In Pakistan, in situ conservation status of Margalla Hills National Park

and Machyara National Park in Azad Kashmir has been discussed, and measures have been suggested for their improvement (Khan et al. 1996).

Conservationists have traditionally viewed on-site and off-site conservation as two very different and alternative approaches. In situ (on-site) conservation involves nature reserves, national parks, and other protected areas. Ex situ (off-site) conservation has traditionally been the task of botanic gardens and arboreta—collections of living plants and gene banks, which usually conserve packaged seeds in long-term storage, but sometimes also tissue cultures or even DNA libraries. In these cases, ex situ conservation can be very useful, and may even be the only efficient way to save a species. Attention should be given to ways in which the genetic diversity of species can be preserved and maintained. The purpose of ex situ conservation is to provide protective custody to endangered species for reintroduction into damaged habitats and to enhance populations as part of ecosystem management.

In Pakistan, the ex situ cultivation of some medicinal plants like *Plantago ovata, Glycyrrhiza glabra, Colchicum luteum, Rheum emodi, Podophyllum hexandrum,* and *Dioscorea deltoidea* has been done outside from their native habitats (Khan 1957). However, ex situ conservation faces some major challenges and one of them is loss of genetic integrity of collections. The genetic decline in the quality ex situ of collections of endangered species can make it impossible for them to survive under natural conditions and, thus, render them useless for reintroduction purposes (Barrett and Kohn 1991)

The term *sircasitum* conservation has been proposed for a range of practices that are intermediate between "traditional" in situ and ex situ conservation. They are associated especially with more traditional (and biodiversity rich) agricultural systems (Hawkes et al. 2001). They include the retention of "wild" plants when land is cleared for agriculture and when crops are weeded, the growing of "wild" plants in home gardens, and the storage of crop seed in granaries for later replanting. All are common practices in the study area.

18.4.4 Threatened Flora and Conservation Status

With no link between use and responsibility, and high and probably ever-growing local demands for fuelwood, fodder, and grazing land, it can safely be predicted that the quality of the forest will decline unless systems of local resources management are improved. In the long run, there will be no benefits from resource depletion. Fewer resources will be available to the local people, leopards and rare pheasants will be lost, and the quality of the catchment will deteriorate. This will have serious consequences because millions of people in the lowlands rely on the steady flow of rivers from this and other forested area in the Himalayas. The whole threatened flora is ethnobotanically valued and is utilized for various purposes in the area. The problem of global biodiversity loss is complex but continuing losses threaten direct economic values and the integrity of ecosystems and their function. Attention is required to the management and protection of various ecosystems including in situ and ex situ conservation of species. We should focus on hot spots that are threatened by destruction and degradation. Attentions should be given to ways in which the genetic diversity of species can be preserved and maintained.

18.4.5 Ethnobotany as a Mean of Nature Conservation

The global effort to conserve and protect the natural environment is a recent phenomenon, though efforts to conserve economically important natural resources have a long history. Humans may have been responsible for the extinction of most of the flora and fauna. Ethnobotany and conservation are inseparable and conservation is one of the most valued tasks of ethnobotanist. Besides, the in situ and ex situ conservational techniques adopted by the ethnobotanist, the local communities are educated on the importance of conservation for the prevailing ecosystems as well as their socioeconomic conditions. A number of countries have set up ethnobotanical facilities and institutions to study traditional medicines or specific projects to study plants used in traditional medicine by various people in their country. The continuation of studying plants and their uses should continue to yield nature conservation, community-based development, and improvement of modern medicine. Forest department and other government agencies view communities as the common enemy, which, of course, is self-defeating, as they could so easily become a part of the solution, rather than being perceived as the problem. From the management point of view, the forest department is hamstrung by a shortage of suitably trained personnel, meager resource allocation, the absence of a resource inventory, inadequate ecological research, etc. With biodiversity conservation traditionally figuring low in the government's priorities, the obvious solution would be to enlist the key stakeholders, namely the communities and other emerging players in the private sector. The centrality of communities to biodiversity conservation and the risk of ignoring it are self-evident. Few efforts have been directed at raising public awareness and education in areas adjacent to protected area, providing environmentally sound and sustainable development assistance to local communities, or formulating appropriate packages of incentive and disincentives. More fundamentally, awareness-raising incentives are part of a process, which entails recognition of community rights to own and control their territories.

18.4.6 Conservation Through Community Participation

Communication, education, and the raising of public awareness about the importance of plant diversity are crucial for the achievement of all the targets of a plant conservation strategy. This target is understood to refer to both informal and formal education at all levels, including primary, secondary, and tertiary education. The Himalayan Jungle Project (HJP) has worked since 1991 with local communities in the Palas valley situated in two districts, Kohistan and Batgram of NWFP, Pakistan. It aimed at protecting one of the richest areas of biological diversity in Pakistan. Its approach was to empower and enable local communities to establish sustainable, integrated natural resource management in the valley, and, so, to reduce any obligation to degrade the natural heritage (Bass 1994). Indigenous knowledge utilization for conservation has introduced a new idea of "ethnoconservation biology"—the incorporation of indigenous conservations models into wild lands management (Balik and Cox 2005). Due to large demography and food security needs of the country, there is no alternative way in which agricultural land reserved for food crops can be utilized for growing medicinal plants. For this purpose, farmers of small holdings are needed to be motivated in an organized manner to grow medicinal plants along with traditional crops in their kitchen garden, wasteland, and bunds of cultivated field rather than promoting big farmers with plans for large plantations. This effort will be useful in poverty alleviation through community participation of rural communities. Such activities will boost up the growth and development of herbal and allied industries.

18.4.7 International Conservation Efforts in Pakistan

Pakistan has been playing a very important role internationally as far as conservation of biodiversity is concerned. From 1970 to1995, Pakistan signed a number of international conventions governing biodiversity which are as follows:

- The Convention on Biodiversity signed in 1992 and ratified it in 1994
- Convention on International Trade in Endangered Species (CITES)
- RAMSAR Convention (Pakistan was Chairman of the standing committee for the year 1987–1990)
- World Heritage Convention
- Convention on the Conservation of Migratory Species
- International Waterfowl and Wetland Bureau
- In addition, Pakistan is a member of the World Conservation Union (IUCN) and the International Waterfowl and Wetland Research Bureau (IWRB).

18.4.8 National Parks and Protected Areas of Pakistan

Over the past three decades, a total of 14 national parks, 99 wildlife sanctuaries, and 96 game reserves have been established, covering an area of 9.17 million hectares, or 10.40 % of the total land area. In this respect, Pakistan lags behind many other Asian countries (including India, Nepal, Sri Lanka, and Bhutan) in term of the national land area that has been designated for conservation (Shinwari et al. 2003).

Table 18.2 National parks of Pakistan. (Source: The IUCN Directory of South Asian Protected Areas 1990 and The Nation May 8th 2003)

	National Park	Region	Size ha	Year
1.	Ayubia	North-West Frontier Province	3312	1984
2.	Central Karakorum	Northern areas	973,845	1995
3.	Chinji	Punjab	6070	1987
4.	ChitralGol	North-West Frontier Province	7750	1984
5.	Deosai plains	Northern areas	363,600	1993
6.	Handrap Shandhoor	Northern areas	51,800	1993
7.	Hazarganji-Chiltan	Baluchistan	15,555	1980
8.	Hingol	Baluchistan	699,088	1997
9.	Khunjerab	Northern areas	227,143	1975
10.	Kirthar	Sindh	308,733	1974
11.	LalSuhanra	Punjab	51,588	1972
12.	Machiara	Azad Jammu and Kashmir	13,593	1996
13.	Margalla hills	Islamabad	17,386	1980
14.	Sheikh Buddin	North-West Frontier Province	15,540	15,540
15.	Lulusar lake	North-West Frontier Province	12,026	2003
16.	Saif-ul-Malook lake	North-West Frontier Province	75,058	2003

IUCN International Union for Conservation of Nature

The main objective of a national park can be defined as the scientific reserve/strict nature reserve to protect nature and maintain natural processes in an undisturbed state in order to have ecologically representative examples of the natural environment available for scientific study, environmental monitoring, education, and for the maintenance of genetic resources in a dynamic and evolutionary state (Table 18.2).

In Pakistan, several sites and areas have been declared protected by IUCN and are given under the control and supervision of various government departments like forest, wildlife, etc. Protected areas are managed mainly for ecosystem, conservation, and recreation. It is interesting to note that out of the total of 16 protected areas, nine are found in NWFP and northern areas.

18.4.9 Concluding Guidelines for Biodiversity Conservation

To supplement the xonservation and improvement efforts the following are some recommendations (Fig. 18.1, 18.2, 18.3, 18.4, 18.5, 18.6, 18.7, 18.8, 18.9, 18.10, 18.11, 18.12, 18.13, 18.14, 18.15 and 18.16):

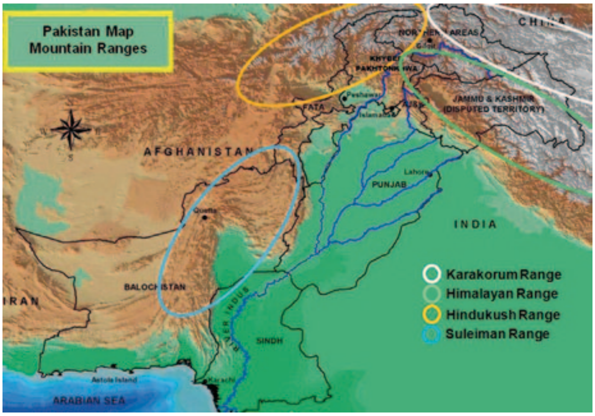

Fig. 18.1 Mountainous ranges of northern Pakistan. (*Source*: http://www.pakistangeographic.com/mountains.html)

Fig. 18.2 A panoramic view of Lake Saif-ul-Malook (Elevation 10,200 ft.)

Fig. 18.3 Floral view of River Kunhar (Elevation 9000 ft.)

Fig. 18.4 Berberis lyceum Royle: A medicinal shrub

Fig. 18.5 Alpine pastures of Deosai, Skardu

Fig. 18.6 A rich temperate forests of Ayubia National Park

Fig. 18.7 Land terracing: A common threat

Fig. 18.8 Roads expension

Fig. 18.9 Unsustainable trade of medicinal plants

Fig. 18.10 Extensive collection of *Skimmia laureola*

Fig. 18.11 Debarking of *Juglans regia* L. for herbal trade

- Habitat loss is a single largest contributing factor for the loss of various species—protect the habitat and the species will protect themselves. Let the species grow themselves without any interference.
- Adopt measures and provide facilities for research on indigenous plants that are threatened.
- Develop proper legislation to protect threatened species.
- Seed banks for important threatened species should be established.
- Indigenous broad-leaved tree species like *Fraxinus excelsior, Acer* sp., *Quercus baloot, Quercus incana, Cornus macrophylla, Betula utilus, Celtis australis, Ulmus wallichiana, Acer caesium, Prunus cornuta,* etc., should be planted in the coniferous forests.
- Efforts should be made for the conservation of medicinal plants via in situ and ex situ conservation, TK of plants lies with the old people that must be scientifically documented.
- Intellectual property rights of the communities concerned having indigenous TK, must be protected.

Fig. 18.12 Earthquake hazards

- Involve local peoples in maintaining their natural resources through a sustainable use program. In this connection, a mass education program should be initiated on maintaining the ecosystems, wildlife, and forests at large.
- The forest department should depute well-trained staff for proper management of the area.
- A crash program is required to have sufficiently trained work force (plant taxonomists and ecologists) to obtain a scientifically accurate data.
- The productivity of existing fuelwood resources can be improved through conservation and management.
- Supply alternative energy resources to local communities to avoid extensive fuelwood cutting.
- Awareness among the people about the conservation of this depleting natural gift should be created through public awareness, media, NGOs and forest department.

Fig. 18.13 Illegal timber trade

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Fig. 18.14 Fuelwood consumption

Fig. 18.15 Extensive cutting of *Taxus wallichiana* as fodder

Fig. 18.16 Overgrazing by nomads in alpine pasture

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Chapter 19
Changes in Tree Species Distribution Along Altitudinal Gradients of Montane Forests in Malaysia

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19.1 Introduction

Due to the variation in biogeography, habitat, and disturbance, tree species in tropical forest varies greatly from place to place in terms of composition and diversity (Whitmore 1998). Altitudinally, the changes in community structure and species composition are influenced by the variation of soil and climatic factors. In addition, other factors such as historical processes, biotic interaction, competition, natural disturbance, and microclimatic are being recognized to play important roles.

In Malaysia, five forest zones are developed from climatic climax formations, i.e., lowland Dipterocarp forest (0–300 m above sea level (a.s.l.)), hill Dipterocarp forest (300–800 m a.s.l.), upper hill Dipterocarp forest (800–1100 m a.s.l.), oak-laurel forest (1100–1600 m a.s.l.) and montane ericaceous forest (above 1600 m a.s.l.) (Symington 2004). These forests are characterized by species composition. The first three forest types are mostly dominated by trees from the Dipterocarpaceae family, hence they are termed as dipterocarp forests. Montane ericaceous and oak-laurel are characterized by an abundance of trees from Fagaceae–Lauraceae and Ericaceae families, respectively. They can be distinguished by a number of structural characters which include the size of canopy height, canopy layer, leaves, and the presence of vascular and nonvascular epiphytes and climbers (Table 19.1). The montane forest also differs from lowland in having fewer and smaller emergent trees, flattish canopy surfaces, gnarled limbs, and denser sub-crowns (Whitmore 1984). The montane ericaceous and oak-laurel forests are moist and are characterized by a thick layer of moss and bryophytes.

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Table 19.1 Structural differences between five forest formations. (van Stennis 1984; Whitmore 1984; Wyatt-Smith 1963; Kiew 1992)

Structural properties	Lowland dipterocarps forest	Hill diptero-carps forest	Upper hill dipterocarps forest	Montane ericaceous forest	Oak-Laurel forest
Canopy height (m)	25–45	25–45	15–33	15–33	1.5–18
Tree canopy layer	Three	Three	Three	Two/one	One
Leaf size	Mesophyll	Mesophyll	Mesophyll	Mesophyll/microphyll	Mesophyll/pachyphyll
Vascular epiphytes	Abundant	Abundant	Abundant	Frequent	Rare
Nonvascular epiphytes	Occasional/abundant	Occasional/abundant	Occasional/abundant	Abundant	Abundant
Climbers	Frequent/abundant	Frequent/abundant	Frequent/abundant	Frequent	Very few
Buttress	Frequent/large	Frequent/large	Frequent/large	Uncommon/absent	Uncommon/absent
Cauliflory	Frequent	Frequent	Frequent	Uncommon/absent	Uncommon/absent

In Peninsular Malaysia, montane rainforest communities are scattered and few. With the exception of Cameron Highlands and Fraser's Hill, they are mainly minimally disturbed, undisturbed, or totally protected such as Gunung Benom in Krau Wildlife Reserve (Latiff and Mohd Shaffea 2011) and Gunung Tahan in Taman Negara Pahang. While both montane ericaceous and oak-laurel forests occupy a relatively small land area in the country, according to Soepadmo (1987), about 25 % of flora in Peninsular Malaysia is confined to these forests. This suggests that floristic composition of montane can be considered as rich in species which is partly due to endemism.

Despite being recognized as among the oldest pristine tropical rain forests in Malaysia, the uniqueness and endemic variety of flora of Imbak Canyon and Mount Ledang have not been fully explored and is scientifically documented. In recognizing the need of providing an inventory of tree species occurring in this area, this chapter aims at identifying the major forest types and tree communities in these areas, studying changes in tree species along altitudinal gradients and presenting the list of tree species collected in the these two areas ranging from lowland forest extending to hill, upper hill, montane, and oak-laurel forest trails. Such basic information is of importance to the understanding of the species distribution, conservation requirements, and economic potential of tree resources which may contribute towards developing and managing the available resources on a sustainable basis.

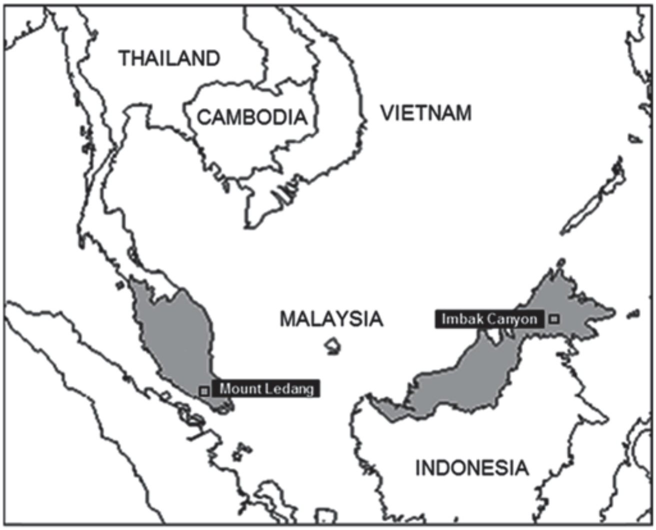

Fig. 19.1 Locations of Mount Ledang and Imbak Canyon, Malaysia

19.2 Material and Methods

19.2.1 Study Areas

19.2.1.1 Imbak Canyon, Sabah

Imbak Canyon is located on the south of Telupid (5°6′34.49″°N, 117°0′9.01″ E) within the Sabah Foundation Conservation Area in the state of Sabah, Malaysia (Fig. 19.1). Landscape of Imbak Canyon is varied from nearly flat, low undulating with river valleys to the hill and montane forest habitats (Fig. 19.2). The orientation and shape of the canyon follow the main river system of Imbak River. The floor of the 25-km canyon lies about 150 m a.s.l., whereas the rim of Canyon rises to more than 1500 m a.s.l. Imbak Canyon is part of Borneo, the third largest island in the world and has been acknowledged as one of the most well-known centers of plant diversity in the world (Soepadmo and Wong 1995). In certain localities in Sabah, where extensive botanical exploration has been conducted, much has been written that the species diversity is extremely high. For example, according to Beaman and Beaman (1990), the Mount Kinabalu Park contains not less than 4000 species of vascular plants in 180 families and 980 genera.

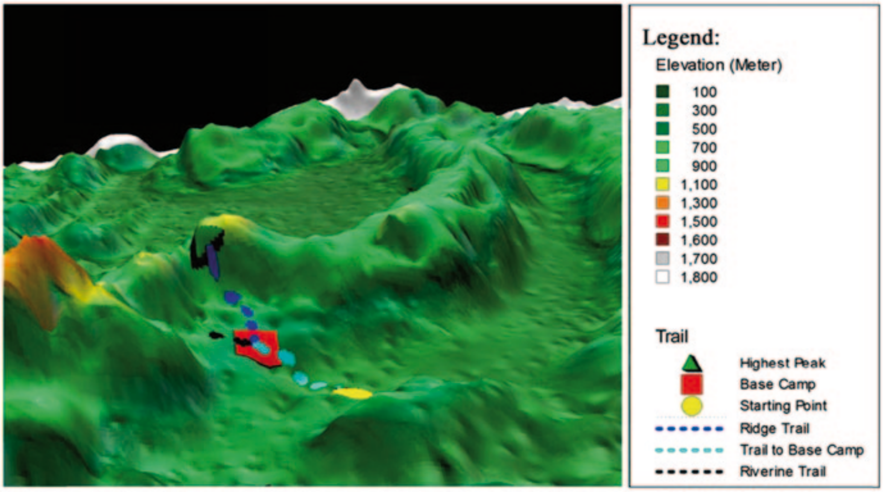

Fig. 19.2 Digital elevation model shows the topography of Imbak Canyon and the expedition trails

19.2.1.2 Mount Ledang National Park, Johor

Mount Ledang, also known as Mount Ophir, is a mountain situated at Gunung Ledang National Park (2°22′27″ N, 102°36′28″ E) in the state of Johor, Malaysia (Fig. 19.1). The mountain is standing at an altitude of 1276 m a.s.l. in the area of 8675.2 ha, and is located between the states of Johor and Malacca. Mount Ledang was gazzetted as a National Park in 2003. The park holds four distinct vegetation types which include lowland dipterocarp forest, hill dipterocarp forest, lower montane, and montane ericaceous.

19.2.1.3 Specimen Collection

Specimen collections in Imbak Canyon were conducted in three localities, viz: (1) the vicinity of the principal base camp of Mount Kuli Research Station, (2) along the riparian forests from the base camp to waterfall (referred to as Riverine trail), and (3) along the forest trail from base camp to the highest point of heath montane forest (known as Ridge trail) (Fig. 19.1). In Mount Ledang, botanical specimens were collected at two trails. These were (1) the forest trail from dam base camp to the upper montane forest at the plateau base camp and continued to the highest point where the telecommunication tower was erected (Fig. 19.3), and (2) along the riparian forest from the park rangers' office.

During the surveys in both locations, attempts were made to make a collection of fresh leaves along with flowers or fruits with the assistance from tree climbers. As collecting complete specimens from canopy tree is often difficult, fallen leaves,

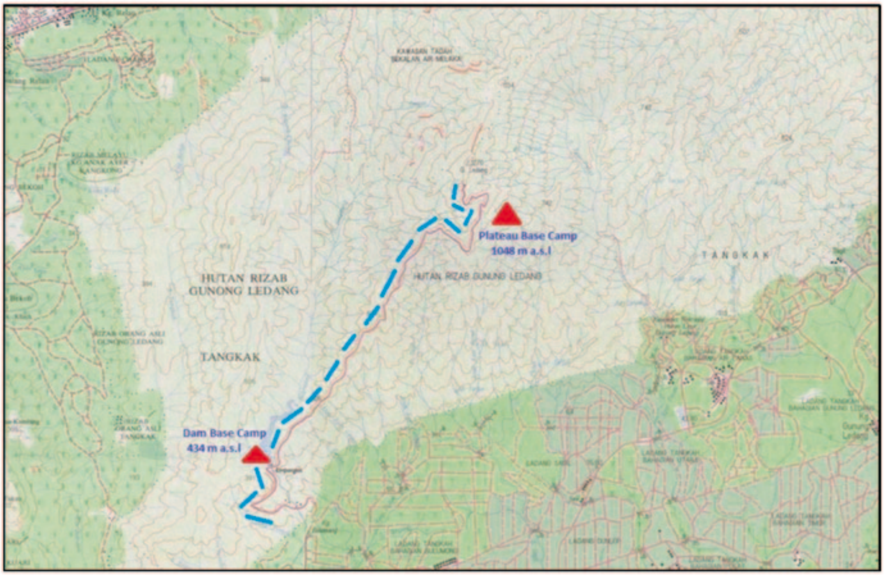

Fig. 19.3 Topographic map of Mount Ledang shows the topography, expedition trail (*blue dotted lines*) and base camp location (in *red triangles*)

fruits, and flowers were collected from the ground. Specimens collected, where possible, were identified during the collection. A GPS receiver was used to determine the topographic elevation of the specific points in the trails. Trail elevation profiles for Imbak Canyon and Mount Ledang were then produced to study the altitudinal changes in tree species distribution along the gradients.

All botanical specimens collected were deposited in the herbarium laboratory of the Centre of Biodiversity and Sustainable Development, Universiti Teknologi MARA, Puncak Alam, Malaysia. Whenever possible, the conservation status of the species was cross-checked with the information from the International Union for Conservation of Nature (IUCN) Red Listdatabase (IUCN 2013). The IUCN red list provides taxonomic, conservation status, and distribution information on taxa that are facing a risk of extinction.

19.3 Results and Discussion

All tree species collected from Imbak Canyon and Mount Ledang were identified and are alphabetically listed in Appendix 1. For Imbak Canyon, the Sabah's vernacular names in the list were referred from the Preferred Check-List of Sabah Trees (Sabah Forestry Department 2005). Whenever possible, the conservation status for the species listed were included based on the information from the IUCN Red List (IUCN 2011).

19.3.1 Tree Communities of Imbak Canyon

From the analysis, it was observed the pristine Imbak Canyon forest holds a high diversity of trees. In all study sites combined, the total number of tree families enumerated along the study trails amounted to 40. Figure 19.4 shows the distribution of tree families found in the study areas in relation to the number of taxa they belong to. Detailed analysis on individual specimens revealed that the families consist of a total of 85 genera and 149 taxa. In terms of tree family, the areas surveyed are rich with the species from the family of Dipterocarpaceae. Specifically, a total of 38 taxa from Dipterocarpaceae family were encountered in the study trails. The second common family is Guttiferae with 13 taxa, followed by Lauraceae (9 taxa), and Leguminosae and Myristicaceae, both account for 8 taxa from the total taxa encountered during the survey periods. Other important families that occur in the study trails include Burseraceae, Euphorbiaceae, Myrtaceae, Rubiaceae, Sterculiaceae, and Podocarpaceae.

19.3.1.1 Riverside Forest and Stream Vegetation

Within and outside the principal base camp in Imbak Canyon are riparian forests that harbor some interesting plant life. Elevation profile of riverine trial associated with the common tree species encountered in the expedition trails is shown in Fig. 19.5. Smaller trees and treelets that are especially common in the riparian forests include *Psychotria* sp., *Rennellia speciosa* (Rubiaceae), *Calophyllum obliquinervium* (Guttiferae), *Canarium denticulatum* (Burseraceae), and *Dillenia excelsa* (Dilleniaceae). Tree species from Dipterocarpaceae (i.e., *Dipterocarpus kunstleri, Shorea macrophylla, Shorea parvifolia,* and *Parashorea tomentella*) are common big trees encountered on both flat ground and farther away from the stream. Besides these, *Hopea nervosa* was frequent and easy to identify by its stilt roots. Below canopy level, the medium-sized to smaller tree species found include *Casearia clarkei* (Flacourtiaceae) and *Neesia* sp. (Bombacaceae). Joining the medium-sized trees are a number of canopy-height trees including *Octomeles sumatrana* (Datiscaceae), *Lithocarpus curtisii* (Fagaceae), and *Duabanga moluccana* (Sonneratiaceae), the latter is characterized by its monopodial branching. A common emergent non-dipterocarp tree species along the riverside is *Koompassia excelsa* (Leguminosae). In openings or gaps of the stream banks, it is not usual to find pioneer species of *Artocarpus anisophyllus* (Moraceae), *Macaranga triloba, Macaranga hypoleuca,* and *Macaranga gigantea* (Euphorbiaceae). Along some open banks and forest edges, the small tree *Vitex pinnata* (Verbanaceae) and *Leea indica* (Leeaceae) are occasionally found.

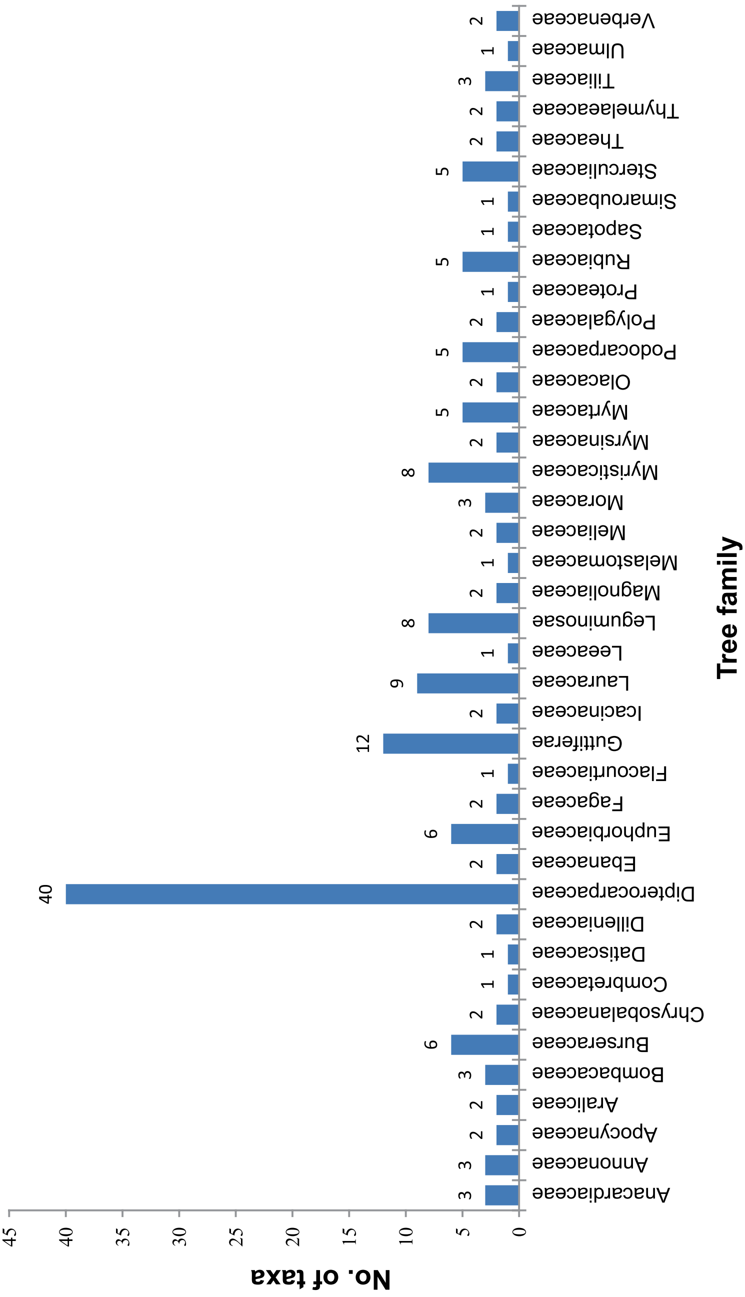

Fig. 19.4 Family-wise distribution of tree species collected from Imbak Canyon, Sabah

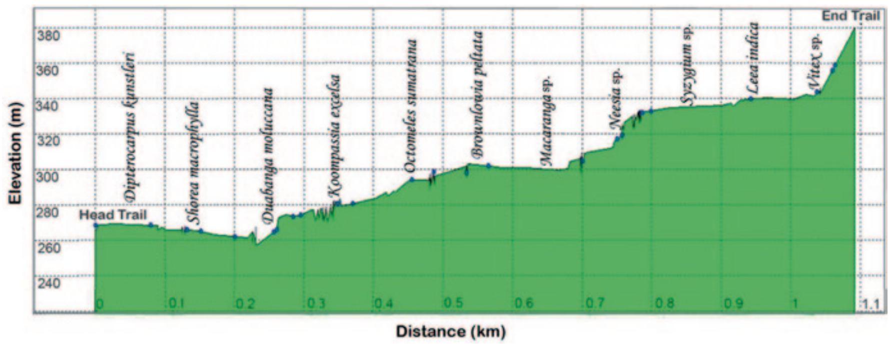

Fig. 19.5 Elevation profile of riparian trails of Imbak Canyon and some common species encountered

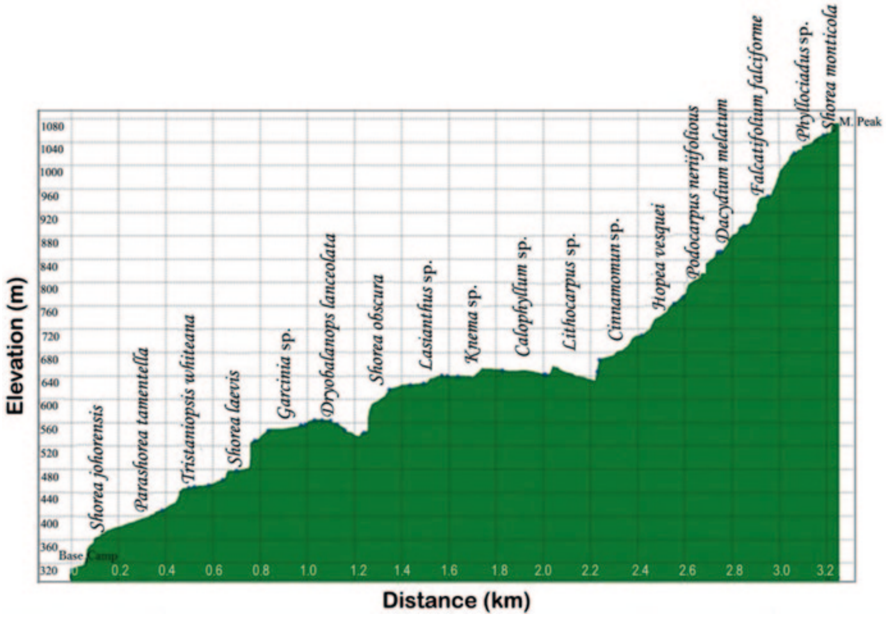

Fig. 19.6 Elevation profile of ridge trail of Imbak Canyon and some common species encountered

19.3.1.2 Lowland, Hill, and Upper Dipterocarp Forests

Figure 19.6 shows an elevation profile of the ridge trail that shows altitudinal changes of tree species. Lowland dipterocarp forests in the expedition areas of Imbak occur from 270 m a.s.l. As the name implies, an interesting character of the lowland dipterocarp forest is the occurrence of dipterocarps within six out of nine genera. These include *Shorea johorensis, Dipterocarpus caudiferus, Parashorea tomentella, Hopea nervosa, Vatica maingayi,* and *Dryobalanops lanceolata*.

Many other groups of plants contribute to the complexity of the forest in Imbak Canyon. A variety of palms (tall palms, understorey palms, and rattans) are especially common, while lianas and epiphytes are frequently encountered in the lowland forests. Small trees that are common in this area include *Glochidion borneensis* (Euphorbiaceae), *Magnolia* sp. (Magnoliaceae), *Actinodaphne pruinosa* (Lauraceae), and *Fordia curtisii* (Leguminosae), whereas the common medium-sized trees include *Knema stenophylla* subsp. *longipedicellate, Horsfieldia polyspherula* (Myristicaeae), *Heritiera javanica* (Sterculiaceae), *Mezzettia leptopoda* (Anonaceae), and *Garcinia* sp. (Guttiferae)*. Horsfieldia and Knema* can be identified by their red sap from the inner bark. Along the trail, different tree communities were observed towards higher elevation to ridge trail. Here, *Tristaniopsis whiteana* (Myrtaceae) is common, distinctive by its peeling barks with mixed reddish brown to gray-white hues. *Diospyros wallichii* (Ebenaceae) grows occasionally and is conspicuous in this forest by its black bark. Other tree includes *Gluta aptera* (Anacardiaceae), which can be identified among other trees by its black sap from the inner bark.

Within the hill dipterocarp forests, tree species from the genus of *Shorea* (Dipterocarpaceae) are common big trees encountered along the trails. These include *Shorea obscura, Shorea laevis, Shorea maxwelliana,* and *Shorea guiso*. They are much encountered on the upper hill dipterocarp forests. Together with these emergent dipterocarps are a number of big non-dipterocarp trees such as *Lithocarpus ewyckii* (Fagaceae), *Parinari oblongifolia* (Chrysobalanaceae), *Campnosperma squamatum* (Anacardiaceae), and *Sindora echinocalyx* (Leguminosae). Smaller trees occasionally encountered along the upper hill forests include *Lasianthus* sp. (Rubiaceae), *Dysoxylon* sp. (Meliaceae), *Payena maingayi* (Sapotaceae), and *Polyalthia cauliflora* (Anonaceae). At the time of the study, *Polyalthia cauliflora* was among a few flowering trees with the inflorences borne on the main trunk.

19.3.1.3 Lower Montane Forest

Lower montane forest was observed before the peak of ridge trails with the presence of lower montane vegetation at 895 m a.s.l. At this elevation, dipterocarps and other common lowland families such as Leguminosae, Euphorbiaceae, and Myristiceae begin to diminish and replace by a diversity of species from tree families such as Myrtaceae, Fagaceae, and Lauraceae. At this elevation, *Syzygium* sp. (Myrtaceae), and *Calophyllum nodusum, Calophyllum depresinervosum* (Guttiferae), and *Schefflera* sp. (Araliaceae) form the main tree association. At 950 m altitude, the forest is mossy and is characterized with low-statured vegetation and devoid of emergent trees.

19.3.1.4 Summit Zone of Ridge Trail

The summit zone occurs on the ridge trail (1080 m a.s.l), among highest peaks in Imbak Canyon. The forest type in summit zone is montane heath forest. Heath forest, also known as kerangas forest occurs on acidic sandy soils that are result of the area's siliceous parent rocks. Within the summit zone, trees from the family of Podocarpaceae are very common montane taxa such as *Podocarpus neriifolius*, *Dacrydium elatum, Falcatifolium falciforme,* and *Phyllocladus* sp. The first two species are much encountered before the summit, whereas *Falcatifolium falciforme* and *Phyllocladus* sp. are distinctly common around the summit zone. This elevation zone also supports a large variety of pitcher plants. Other montane taxa such as *Acronychia* sp. (Rutaceae) as well as *Lindera montanoides* (Lauraceae) also occur. An interesting finding of the montane health forest of Imbak Canyon is the occurrence of the only dipterocarp *Shorea monticola* in the summit zone despite its absence in the lower elevation (Fig. 19.5).

19.3.2 Tree Species of Special Interest in Imbak Canyon

Imbak Canyon is an interesting conservation area in terms of landscape variation and conservation potential. It shelters species that are endemic to the area although they may be found in other parts of Borneo. Of all trees documented, four taxa are reported to be endemic to Borneo. These include *Knema stenophylla* subsp. *longipedicellate, Dryobalanops lanceolata, Actinodaphne montana,* and *Shorea monticola* (Appendix 1). *Knema stenophylla* subsp. *longipedicellate* normally occurs in lowland dipterocarp forest to lower montane forests (de Wilde 2000). In this survey, the species was found at the ridge trail of about 795 m a.s.l. Ashton (2004) reported that *Dryobalanops lanceolata* is common and widespread in Sabah, Sarawak, and Brunei. In this study, this taxon was observed to form abundant saplings under the closed canopy mostly on the lowland areas and lower slopes up to 700 m altitude.

Shorea monticola is another endemic species of Borneo commonly found in the upper limits of upper dipterocarp forests at 600–1500 m altitude. In Imbak Canyon area, this species is found at the peak of ridge trail of 1080 m altitude. Ashton (2004) reported that this taxon also commonly occurs in Kinabalu National Park and Mulu National Park in Sarawak.

The IUCN Red List data were used to provide the information on the conservation status of some of listed tree species collected from this survey. Based on the list, five species from the family of Dipterocarpaceae, viz, *Parashorea malaanonan*, *Vatica maingayi*, *Dipterocarpus grandiflorus*, *Dipterocarpus kunstleri*, and *Shorea johorensis,* are reported to be critically endangered (Appendix 1) which may require a combination of sound research and some conservation attention.

19.3.3 Forest Communities and Tree Flora of Mount Ledang

19.3.3.1 Family of Trees

Mount Ledang equally holds a high diversity of trees with a total number tree families enumerated from all study areas amounting to 62. Figure 19.7 shows the distribution of tree families that occur in the study area in relation to the number of taxa. Observations of specimens indicated that the tree families consist of 143 genera and 222 taxa. Generally, the areas surveyed are rich with the species from the family of Myrtaceae. Overall, a total of 24 taxa which belong to Myrtaceae family were encountered in the study trails. The second was the family of Euphorbiaceae with 21 taxa, followed by Moraceae (18 taxa), Dipterocarpaceae (17 taxa), and Rubiaceae (15 taxa). The next five important tree families that occur in the study trails include Theaceae, Guttiferae, Apocynaceae, Leguminosae, and Hypericaceae, with a number of taxa ranging from 10 to 13. Twelve families recorded the number of taxa between 5 and 9, and the remaining 40 families with the range of 1–4 taxa (Fig. 19.7).

19.3.3.2 Tree Communities in the Riparian Forests of Mount Ledang

Riparian forests are narrow, ribbon-like corridors that occur adjacent to many streams (Baker et al. 2002). The ecological structure and function of riparian forests and the associated streams are profoundly intertwined. According to Damasceno-Junior et al. (2005), variations in topography, landform, and soils in riparian forests have strong effects on species composition, distribution, and structure. Near the park rangers' office of Mount Ledang National Park are riparian forests that harbor some interesting plant life. The river flows down through rocky mountain and many cascades at different heights which created many small pools. Smaller trees and treelets that are especially common in the moist areas include *Ixora* sp., *Rennellia elliptica, Canthium didymium* (Rubiaceae), *Barringtonia macrostachya* (Lecythidaceae), *Baccaurea parviflora* (Phyllanthaceae), and *Microcos latifolia* (Tiliaceae). Besides these, *Saraca multiflora* (Leguminosae) was frequent and easy to identify by its purple young leaves hanging from the ends of the branchlets.

Tree species from Dipterocarpaceae (i.e., *Shorea multiflora*), Moraceae (i.e., *Artocarpus elasticus*), Sapotaceae (i.e., *Palaquium obovatum*), and Leguminosae (i.e., *Sindora coriacea* and *Dialium platysepalum*) are big trees encountered on farther away from the stream. *Dillenia reticulata* (Dilleniaceae) can be identified from its big obovate leaves and stilt roots. Other medium-sized tree species found include *Knema scortechinii* (Myristicaceae), *Diospyros styraformis* (Ebenaceae), and *Ixonanthes reticulata* (Ixonanthaceae). *Knema* is distinguished by its red sap produced from the stem from a slight incision made on the bark, whereas *Diospyros* by its distinctive black bark, and *Ixonanthes* by its bole which often fluted. In the openings or gaps of the stream banks, it is not usual to find pioneer species from Euphorbiaceae (i.e., *Croton argyratus, Croton laevifolius,* and *Macaranga* sp.).

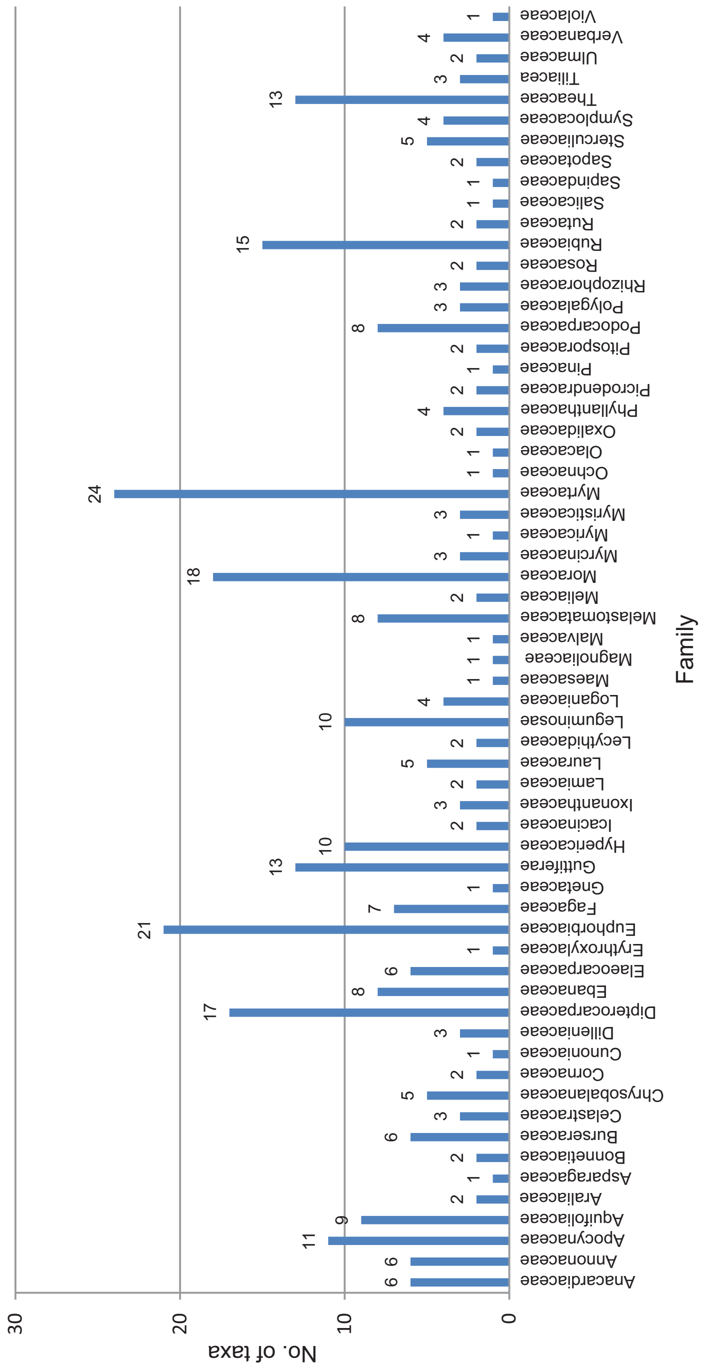

Fig. 19.7 Family-wise distribution of tree species collected from Mount Ledang

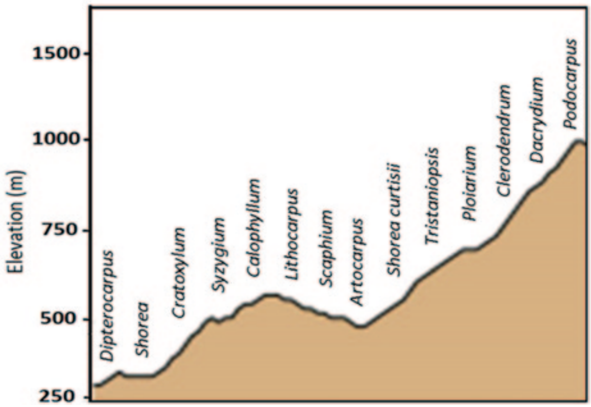

Fig. 19.8 Trail elevation profile and some common genus encountered in Mount Ledang

19.3.3.3 Lowland, Hill, and Upper Hill Dipterocarp Forests

The expedition trail and its elevation profile for the journey to the peak of Mount Ledang are presented in Figs. 19.3 and 19.8, respectively. The exploration began from the lowland dipterocarp forest zone at 257 m altitude. As the name implies, the Dipterocarpaceae are mainly lowland rainforest trees. Trees from this family are the most important timber in Malaysia. A number of *Dipterocarpus* and *Shorea* were found in this area. These include *Dipterocarpus crinitus, Dipterocarpus cornutus, Dipterocarpus kerrii,* and *Dipterocarpus kunstleri*. Five species of *Shorea* encountered along the trails were *Shorea leprosula, Shorea macroptera, Shorea parvifolia, Shorea pauciflora,* and *Shorea ovalis*. Other dipterocarps found within this elevation include *Anisoptera curtisii*. Trees from Dipterocarpaceae can be identified from the barks which usually produce resins. Other emergent trees from non-dipterocarp group found in this area include *Koompassia malaccensis* (Leguminosae), *Ochanostachys amentacea* (Olacaceae), and *Dyera costulata* (Apocynaceae).

Small and medium-sized trees that are common in this area include *Cinnamomum iners* (Lauraceae), *Gardenia tubifera* (Rubiaceae), *Gnetum gnemon* (Gnetaceae), *Memecylon cantleyi* (Melastomataceae), and *Pimelodendron griffithianum* (Euphorbiaceae). *Cinnamomum* can be identified by its aromatic smell from the inner bark and its trinerved leaf characters. Other than timber trees, many other groups of plants contribute to the complexity of the lowland dipterocarp forests. For example, a variety of bamboo, rattans, and palms are especially common as well as climbers and epiphytes.

Different tree communities occurred in the higher elevation along the trail to the peak of Mount Ledang. In the hill dipterocarp forests, *Shorea platyclados* (Dipterocarpaceae) is common. Tree non-dipterocarp species such as *Cratoxylum formosum* (Hypericaceae), *Syzygium filifrome* (Myrtaceae), *Calophyllum* sp. (Guttiferae), and *Gluta wallichii* (Anacardiaceae) grow occasionally in this zone. *Cratoxylum* is distinctive from its iodine-colored sap from the inner bark and its prickly stem. *Syzygium* can be indentified from its simple opposite leaf arrangement and *jambu* smell characters, whereas *Calophyllum* also from its simple and opposite leaf arrangement but with parallel secondary veins. Meanwhile, *Gluta* can be distinguished from other trees by its black sap from the inner bark.

In the open sites of hill dipterocarp forest, some pioneer species such as *Macaranga gigantea, Macaranga triloba, Sapium baccatum, Endospermum diadenum* (all from Euphorbiaceae), and *Cratoxylum cochinchinense* (Hypericaceae) are common. Together with these secondary species, a number of medium-sized non-dipterocarp trees such as *Lithocarpus* sp. (Fagaceae), *Scaphium macropodum* (Sterculiaceae), and *Artocarpus scortechinii* (Moraceae) were encountered along the hill dipterocarp forests.

Within the upper hill dipterocarp forest, tree species of *Shorea* (Dipterocarpaceae) are very common big trees along the trails. These include *Shorea curtisii* and *Shorea exelliptica. Shorea curtisii is* a typical member of upper hill forest habitat, specifically in valleys of the hill. It is a large emergent tree with a straight and fissured bole. Together with these emergent dipterocarps are a number of non-dipterocarp trees such as *Gynotroches axillaris* (Rhizophoraceae), *Elaeocarpus floribundus* (Elaeocarpaceae), and *Tristaniopsis razakiana* (Myrtaceae). *Tristaniopsis* is distinctive in terms of its peeling barks with mixed reddish brown to gray-white hues. Smaller trees occasionally encountered along the upper hill trails include *Randia scortechinii, Timonius wallichianus* (Rubiaceae), *Scutinanthe brunnea* (Burseraceae), and *Gynotroches axillaris* (*Rhizophoraceae*).

19.3.3.4 Lower Montane Forest

During the expedition, lower montane forest was observed before the peak of trails with the presence of lower montane vegetation (e.g., *Ploiarium alternifolium*—Bonnetiaceae) at 1018 m altitude. At this altitude, dipterocarps and other common lowland families such as Leguminosae, Euphorbiaceae, and Myristiceae begin to diminish and are replaced by a diversity of species from tree families such as Myrtaceae and Theaceae At this elevation, *Baeckea frutescens, Leptospermum flavescens* (Myrtaceae), and *Eurya nitida* (Theaceae) form the main tree association. At 1030 m altitude, the forest is mossy and is characterized with low-statured vegetation and devoid of emergent trees.

19.3.3.5 Upper Montane Forest

The upper montane zone occurs on area of telecommunication tower at the end of the trail (1190 m altitude) which is among the highest peaks in Mount Ledang. Within the zone, trees from the family of Podocarpaceae are very common montane

Fig. 19.9 *Maesa fraseriana*

taxa such as *Podocarpus neriifolius, Dacrydium elatum,* and *Dacrydium beccarii.* They are also much encountered along the trails before the summit. Together with these communities are *Magnolia montana* (Magnoliaceae), *Ardisia retinervia* (Myrcinaceae), and *Mastixia retinervia* (Cornaceae) which distinctly common around the summit zone. This elevation zone also supports a large variety of pitcher (Nepenthacaeae) and ginger (Zingiberaceae) plants. Other montane taxa such as *Clerodendrum* sp. (Lamiaceae), *Schima wallichii* (Theaceae)*, Leptospermum flavescens* (Myrtaceae), as well as *Ficus* cf. *sinuata* (Moraceae) also occur.

19.3.4 Maesa fraseriana: A Potential New Record for Mount Ledang

Maesa fraseriana, belonging to Maesaceae, is a small shrub (up to 2 m tall) or woody climbers (up to 7 m tall) that is endemic to montane forest of Fraser's Hill (Fig. 19.9). Utteridge (2012) reported that this species is known from five localities based on ten collections. All collection was from Fraser's Hill except for a single outlier from Ulu Klang. However, according to Utteridge (2012), it is possible that *Maesa fraseriana* is found within the central range of Peninsular Malaysia with an extent of occurrence of the collection within 1000 km^2. Due to the evidence of habitat decline in Fraser's Hill, this species was assigned a rating of Endangered B1 ab (iii).

It is interesting to note that, during this expedition, this taxon was found at the moist forest edge (1048 m altitude) near the roadside of plateau base camp, together with other montane taxa such as *Dacrydium elatum, Eurya nitida,* and *Podocarpus neriifolius.* Identification of this species was made possible from a consultation with Forest Research Institute Malaysia's (FRIM's) herbarium personnel and a thorough literature review. According to Kiew (1992), as compared to lowland forests, endemic species in montane forest may only be confined to a single mountain peak or group of peaks in which in this expedition, this phenomenon is illustrated by the discovery of *Maesa fraseriana*. In contrast, the geological distribution for the species in the lowland forests is wider. Therefore, the discovery of a new record from the montane forest may have profound implications of conservation as disturbance in the small habitat could affect the survival of the species.

19.3.5 Other Species of Interest

Mount Gunung is an interesting area in terms of geographical variation, species composition, and conservation potential. It shelters species that are endemics and endangered not to the area but also from other parts of Malaysia. The IUCN Red List data were used to provide the information on the conservation status of the listed tree species collected from this survey. In terms of conservation status, among all trees documented, *Anisoptera curtisii* and *Dipterocarpus cornutus* are assigned as Critically Endangered (IUCN 2013). The other four species from the family of Dipterocarpaceae, viz, *Shorea leprosula, Shorea platyclados, Shorea pauciflora,* and *Dipterocarpus kerrii,* are reported to be endangered (Appendix 1) which may require a combination of sound research and some conservation attention.

Conclusion

Imbak Canyon and Mount Ledang cover a diverse range of landscape elements and natural vegetation communities from streamside vegetation, lowland, hill, and upper hill mixed dipterocarps up to lower montane heath forests. While information from this survey may provide reference for ecologically useful species as well as species of special concern, sufficiently large-range surveys are still required to gather more comprehensive information to identify conservation efforts for sustainability of forest biodiversity. The areas are likely to harbor a significant number of endemic species; however, the data collected from this expedition were inadequate to document comprehensive information on species richness, endemism, and checklists of rare and endangered species for the area. While information from this survey may provide reference for ecologically useful species as well as species of special concern, follow-up plant inventories are necessary to assess the conservation importance of a particular species.

Appendix 1: List of Trees in Alphabetical Order Documented for the Imbak Canyon and Mount Ledang, Malaysia

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
1	*Acronychia porteri*		Rutaceae	Lower risk/least concern	ML/IC
2	*Acronychia* sp.		Rutaceae		IC
3	*Actinodaphne montana*	Medang paying	Lauraceae	Lower risk/least concern/ endemic	IC
4	*Actinodaphne pruinosa*	Medang payung gunung/Medang serai	Lauraceae	Lower risk/least concern	IC/ML
5	*Actinodaphne* sp.	Medang serai	Lauraceae		IC
6	*Adinandra dumosa*	Tetiup	Theaceae		ML
7	*Adinandra maculosa*	Bawing	Theaceae		IC
8	*Aglaia eximia*	Bekak	Meliaceae		ML
9	*Aglaia* sp.	Bekak	Meliaceae		ML
10	*Agrostistachys longifolia*	Jenjulong	Euphorbiaceae		ML
11	*Alstonia angustiloba*	Pulai/Pulai bukit	Apocynaceae		IC/ML
12	*Alstonia macrophylla*	Pulai penipu bukit	Apocynaceae		ML
13	*Anaxagorea javanica*	Bunga pompun	Annonaceae		ML
14	*Anisoptera cutisii*	Mersawa durian	Dipterocarpaceae	Critically endangered	ML
15	*Aporusa microstachya*		Phyllanthaceae		ML
16	*Aquilaria malaccensis*	Gaharu	Thymelaeaceae	Vulnerable	IC
17	*Ardisia retinervia*		Myrcinaceae		ML
18	*Ardisia* sp.	Serusop	Myrsinaceae		IC/ML
19	*Arthrophyllum diversifolium*	Terentang	Araliaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
20	*Artocarpus anisophyllus*	Terap ikal	Moraceae		IC
21	*Artocarpus dadah*	Tampang bulu	Moraceae		ML
22	*Artocarpus elasticus*	Terap nasi	Moraceae		IC/ML
23	*Artocarpus heterophyllus*	Nangka	Moraceae		ML
24	*Artocarpus lanceifolius*	Keledang-keledang	Moraceae		ML
25	*Artocarpus scortechinii*	Terap hitam	Moraceae		ML
26	*Arytera littoralis*		Sapindaceae		ML
27	*Austrobuxus nitidus*		Picrodendraceae		ML
28	*Baccaurea parviflora*	Kunau-kunau/Rambai hutan/Set-ambun taik	Euphorbiaceae		IC/ML
29	*Baeckea frutescens*	Chuchor atap	Myrtaceae		ML
30	*Barringtonia macrostachya*	Putat	Lecythidaceae		ML
31	*Bouea oppositifolia*	Kudang daun kecil	Anacardiaceae		ML
32	*Brackenridgea palustris*	Mata ketam	Ochnaceae	Lower risk/near threatened	ML
33	*Breynia* sp.		Phyllanthaceae		ML
34	*Brownlowia peltata*	Pinggau-pinggau	Tiliaceae		IC
35	*Buchanania sessifolia*	Otak udang daun tajam	Anacardiaceae		ML
36	*Callerya atropurpurea*	Tulang daing	Leguminosae		ML
37	*Calophylllum tetrapterum*	Bintangor	Guttiferae	Lower risk/least concern	IC
38	*Calophyllum* sp.	Bintangor	Guttiferae		ML
39	*Calophyllum depresinervosum*	Bintangor	Guttiferae		IC
40	*Calophyllum dioscurii*	Bintangor	Guttiferae		IC
41	*Calophyllum macrocarpum*	Bintangor	Guttiferae		ML
42	*Calophyllum nodosum*	Bintangor	Guttiferae		IC
43	*Calophyllum obliquinevium*	Bintangor	Guttiferae		IC

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
44	*Calophyllum* sp. 1	Bintangor	Guttiferae		IC
45	*Calophyllum* sp. 2	Bintangor	Guttiferae		IC
46	*Calophyllum wallichianum var wallichianum*	Bintangor	Guttiferae		IC
47	*Campnosperma auriculatum*	Terentang daun besar	Anacardiaceae		IC/ML
48	*Campnosperma squamatum*	Terentang daun kecil	Anacardiaceae		IC
49	*Canarium denticulatum*	Kedondong	Burseraceae		IC
50	*Canarium littorale*	Kedondong gergaji	Burseraceae	Lower risk/least concern	IC/ML
51	*Canarium pilosum*	Kendondong	Burseraceae		IC
52	*Canthium didymum*		Rubiaceae		ML
53	*Carallia brachiata*	Meransi	Rhizophoraceae		ML
54	*Casearia clarkei*		Flacourtiaceae		IC
55	*Castanopsis megacarpa*	Beranggang gajah/getek tangga	Fagaceae		ML
56	*Castanopsis megacarpa*	Gertik tangga	Fagaceae		ML
57	*Chisochiton ceramicus*	Berindu	Meliaceae		IC
58	*Cinnamomum iners*	Kayumanis/Medang teja	Lauraceae		IC/ML
59	*Cinnamomum javanicum*	Kayu manis	Lauraceae		IC
60	*Cinnamomum* sp.	Medang	Lauraceae		IC
61	*Clerodendrum* sp.		Lamiaceae		ML
62	*Clerodendrum villosum*		Lamiaceae		ML
63	*Cratoxylum cochinchinense*	Geronggang	Hypericaceae	Lower risk/least concern	ML
64	*Cratoxylum formosum*	Geronggang derum	Hypericaceae	Lower risk/least concern	ML
65	*Cratoxylum* sp.	Geronggang	Hypericaceae		ML
66	*Croton argyratus*	Hujan panas	Euphorbiaceae		ML
67	*Croton laevifolius*	Hujan panas	Euphorbiaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
68	*Croton* sp.	Hujan panas	Euphorbiaceae		ML
69	*Crotoxylum formosum*	Geronggang	Hypericaceae	Lower risk/least concern	ML
70	*Cryptocarya ferrea*	Medang	Lauraceae		IC
71	*Cyathocalyx pruniferus*		Annonaceae		ML
72	*Dacrydium beccarii*	Ekor tupai	Podocarpaceae	Least concern	ML
73	*Dacrydium comosum*	Ekor	Podocarpaceae	Endangered	IC
74	*Dacrydium elatum*	Ekor kuda	Podocarpaceae	Lower risk/least concern	ML
75	*Dacryodes rostrata*	Kedondong kerut	Burseraceae	Lower risk/least concern	ML
76	*Dacryodes rubiginosa*	Kedondong	Burseraceae		IC
77	*Desmos chinensis*	Pisang monyet	Annonaceae		IC
78	*Dialium platysepalum*	Keranji kuning besar	Leguminosae		ML
79	*Dillenia borneensis*	Simpoh gajah	Dilleniaceae		IC
80	*Dillenia excelsa*	Simpoh laki	Dilleniaceae		IC
81	*Dillenia reticulata*	Simpoh gajah	Dilleniaceae		ML
82	*Diospyros andamanica*	Kayu arang	Ebenaceae		ML
83	*Diospyros buxifolia*	Meribut	Ebanaceae		ML
84	*Diospyros rigida*	Kayu arang	Ebanaceae		ML
85	*Diospyros* sp.	Kayu arang	Ebanaceae		IC/ML
86	*Diospyros styraformis*	Kayu arang	Ebanaceae		ML
87	*Diospyros wallichii*	Kayu malam	Ebanaceae		IC
88	*Dipterocarpus* sp.	Keruing	Dipterocarpaceae		ML
89	*Dipterocarpus caudiferus*	Keruing putih	Dipterocarpaceae		IC
90	*Dipterocarpus crinitus*	Keruing mempelas	Dipterocarpaceae		ML
91	*Dipterocarpus grandiflorus*	Keruing belimbing	Dipterocarpaceae	Critically endangered	IC

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
92	*Dipterocarpus kerrii*	Keruing gondol	Dipterocarpaceae	Endangered	ML
93	*Dipterocarpus kunstleri*	Keruing rapak	Dipterocarpaceae	Critically endangered/near streams	IC
94	*Dracaena* sp.		Asparagaceae		ML
95	*Dryobalanops lanceolata*	Kapur paji	Dipterocarpaceae	Endangered/Endemic	IC
96	*Duabanga moluccana*	Megas	Sonneratiaceae	Wet area	IC
97	*Durio griffithii*	Durian kuning	Bombacaceae		IC
98	*Durio oxleyanus*	Durian	Bombacaceae		IC
99	*Dyera costulata*	Jelutong/Jelutong bukit	Apocynaceae	Lower risk/least concern	IC/ML
100	*Dysoxylon* sp.	Olop-olop	Meliaceae		IC
101	*Elaeocarpus floribundus*	Mendung	Elaeocarpaceae		ML
102	*Elaeocarpus nitidus var. nitidus*	Mendung	Elaeocarpaceae		ML
103	*Elaeocarpus palembanicus*	Mendung	Elaeocarpaceae		ML
104	*Elaeocarpus* sp.	Mendung	Elaeocarpaceae		ML
105	*Elateriospermum tapos*	Perah	Euphorbiaceae		ML
106	*Endospermum diadenum*	Sesenduk	Euphorbiaceae		ML
107	*Erythroxylum cuneatum*		Erythroxylaceae		ML
108	*Eucalyptus deglupta*	Kayu putih	Myrtaceae		ML
109	*Eurya nitida*	Podo kebal musang	Theaceae		ML
110	*Eurycoma longifolia*	Pahit-pahit	Simaroubaceae		IC
111	*Fagraea crenulata*	Tembusu	Loganiaceae		ML
112	*Falcatifolium falciforme*	Podo	Podocarpaceae	Lower risk/least concern	IC
113	*Ficus* sp.	Ara	Moraceae		IC/ML
114	*Ficus* cf. *sinuata*	Ara	Moraceae		ML
115	*Ficus deltoidea*	Mas cotek	Moraceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
116	*Ficus fulva*	Ara	Moraceae		ML
117	*Ficus glossularioides*	Ara	Moraceae		ML
118	*Ficus vasculosa*	Kayu ara	Moraceae		IC
119	*Ficus xylophylla*	Ara	Moraceae		ML
120	*Fordia curtisii*		Leguminosae		IC
121	*Fordia* sp.		Leguminosae		IC
122	*Garcinia malaccensis*	Manggis hutan/Kandis	Guttiferae		IC/ML
123	*Garcinia* sp.	Kandis	Guttiferae		IC/ML
124	*Gardenia tubifera*	Mentiong bukit	Rubiaceae		ML
125	*Gironniera subaequalis*	Ampas tebu/Hampas tebu	Ulmaceae		IC/ML
126	*Glochidion borneensis*	Ubah nasi	Euphorbiaceae		IC
127	*Glochidion superbum*	Gerumong jantan	Euphorbiaceae		IC
128	*Gluta aptera*	Rengas/Rengas kerbau jalang	Anacardiaceae		IC/ML
129	*Gluta elegans*	Rengas	Apocynaceae		ML
130	*Gluta wallichii*	Rengas	Anacardiaceae		ML
131	*Gnetum gnemon*	Meninjau	Gnetaceae	Least concern	ML
132	*Gonocaryum gracile*		Icacinaceae		ML
133	*Gordonia concentricicatrix*	Semak pulut	Theaceae		ML
134	*Gordonia* sp.	Samak pulut	Theaceae		ML
135	*Gymnacranthera forbesii*	Lanau	Myristicaceae		IC
136	*Gynotroches axillaris*		Rhizophoraceae		ML
137	*Helicia* sp.		Proteaceae		IC
138	*Heritiera elata*	Kembang	Sterculiaceae		IC
139	*Heritiera javanica*	Kembang	Sterculiaceae		IC

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
140	*Homalium longifolium*	Telur buaya	Sterculiaceae	Lower risk/least concern	ML
141	*Hopea nervosa*	Selangan jangkang	Dipterocarpaceae		IC
142	*Hopea* sp. 1	Selangan	Dipterocarpaceae		IC
143	*Hopea* sp. 2	Selangan	Dipterocarpaceae		IC
144	*Hopea vesquei*	Selangan bukit karangas	Dipterocarpaceae		IC
145	*Horsfieldia guatteriifolia*	Darah-darah	Myristicaceae		IC
146	*Horsfieldia polyspherula*	Darah-darah	Myristicaceae		IC
147	*Horsfieldia* sp.	Darah-darah	Myristicaceae		IC
148	*Ilex cymosa*	Mensirah	Aquifoliaceae		ML
149	*Ilex macrophylla*	Mensirah	Aquifoliaceae		ML
150	*Ilex* sp.	Mensirah	Aquifoliaceae		ML
151	*Ilex triflora*	Mensirah	Aquifoliaceae		ML
152	*Irvingia malayana*	Pauh kijang	Irvingiaceae	Lower risk/least concern	IC
153	*Ixonanthes icosandra*	Pagar anak	Ixonanthaceae		ML
154	*Ixonanthes reticulata*	Inggir burung	Ixonanthaceae		ML
155	*Ixora* sp.	Kiam/Jejarum	Rubiaceae		IC/ML
156	*Ixora* sp.	Kiam	Rubiaceae		IC
157	*Knema laurina*	Darah-darah	Myristicaceae		IC
158	*Knema malayana*	Darah-darah	Myristicaceae	Lower risk/least concern	IC
159	*Knema patentinervia*	Penarahan	Myristicaceae		ML
160	*Knema scortechinii*	Penarahan	Myristicaceae		ML
161	*Knema stenophylla* subsp. *longipedicellate*	Darah darah	Myristicaceae	Endemic	IC
162	*Koilodepas longifolium*		Euphorbiaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
163	*Kokoona reflexa*	Mata ulat	Celastraceae		ML
164	*Koompasia malaccensis*	Kempas	Leguminosae	Lower risk/conservation dependent	ML
165	*Koompassia excelsa*	Mengaris	Leguminosae	Lower risk/conservation dependent	IC
166	*Lasianthus* sp.		Rubiaceae		IC
167	*Leea indica*	Mali-mali	Leeaceae		IC
168	*Leptospermum flavescens*	Cina maki	Myrtaceae		ML
169	*Leucostegane latistipulata*	Mempisang	Leguminosae	Vulnerable	IC
170	*Lindera montanoides*	Medang pawas	Lauraceae		IC
171	*Lithocarpus curtisii*	Mempening	Fagaceae	Vulnerable	IC
172	*Lithocarpus encleiscarpus*	Mempening	Fagaceae		IC
173	*Lithocarpus ewyckii*	Mempening	Fagaceae		IC
174	*Lithocarpus* sp.	Mempening	Fagaceae		ML
175	*Lithocarpus wallichianus*	Mempening	Fagaceae		ML
176	*Litsea* sp.	Medang	Lauraceae		ML
177	*Lophopetalum sp.*	Mata ulat	Celastraceae		ML
178	*Macaranga gigantea*	Mahang gajah	Euphorbiaceae		ML
179	*Macaranga hypoleuca*	Sedaman putih/Mahang kapur	Euphorbiaceae		IC/ML
180	*Macaranga laciniata*	Mahang	Euphorbiaceae		ML
181	*Macaranga triloba*	Sedaman/Mahang merah	Euphorbiaceae		ML
182	*Maclurodendron porteri*		Rutaceae		ML
183	*Maesa fraseriana*		Maesaceae	New record for Mount Ledang	ML
184	*Magnolia montana*		Magnoliaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
185	*Magnolia* sp. 2	Cempaka	Magnoliaceae		IC
186	*Mallotus griffithianus*	Balik angin	Euphorbiaceae		ML
187	*Mallotus macrostachyus*	Balik angin	Euphorbiaceae		ML
188	*Mallotus oblongifolius*	Balik angin	Euphorbiaceae		ML
189	*Mallotus* sp.	Balik angin	Euphorbiaceae		ML
190	*Mallotus stipularis*	Mallotus	Euphorbiaceae		IC
191	*Mangifera griffthii*	Rawa	Anacardiaceae		ML
192	*Maranthes corymbosa*	Merbatu	Chrysobalanaceae		ML
193	*Mastixia pentandra*	Tetebu	Cornaceae		ML
194	*Melastoma malabatricum*	Senduduk	Melastomataceae		ML
195	*Memecylon amplexicaule*	Nipis kulit	Melastomataceae		ML
196	*Memecylon cantleyi*	Nipis kulit	Melastomataceae		ML
197	*Memecylon minutiflorum*	Nipis kulit	Melastomataceae		ML
198	*Memecylon pubescens*	Nipis kulit	Melastomataceae		ML
199	*Memecylon* sp.	Nipis kulit	Melastomataceae		ML
200	*Mesua kochummeniana*	Penaga bayan	Guttiferae		ML
201	*Mesua racemosa*	Penaga	Guttiferae		ML
202	*Mesua* sp.	Penaga	Guttiferae		ML
203	*Mezzettia leptopoda*	Mempisang	Annonaceae		IC/ML
204	*Microcos antidesmifolia*	Kerodong	Tiliaceae		IC
205	*Microcos latifolia*	Chenderai	Tiliacea		ML
206	*Microcos* sp.		Tiliacea		ML
207	*Monocarpia marginalis*	Mempisang	Annonaceae		ML
208	*Myrica esculenta*		Myricaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
209	*Nauclea albicinales*		Rubiaceae		ML
210	*Nauclea* sp.		Rubiaceae		ML
211	*Nauclea subdita*	Bangkal kuning	Rubiaceae		IC
212	*Neesia* sp.	Durian monyet	Bombacaceae		IC
213	*Norrisia malaccensis*		Loganiaceae		ML
214	*Ochanostachys amentacea*	Tanggal/Petaling	Olacaceae		IC/ML
215	*Octomeles sumatrana*	Benuang	Datiscaceae	Lower risk/least concern	IC
216	*Oxyspora* sp.		Melastomaceae		IC
217	*Palaquium maingayi*	Nyatoh durian	Sapotaceae		ML
218	*Palaquium obovatum*	Nyatoh	Sapotaceae		ML
219	*Pangium edule*	Kepayang	Salicaceae		ML
220	*Parashorea melaanonan*	Urat mata daun licin	Dipterocarpaceae	Critically endangered	IC
221	*Parashorea tomentella*	Urat mata beludu	Dipterocarpaceae		IC
222	*Parinari elmeri*	Merbatu	Chrysobalanaceae		ML
223	*Parinari oblongifolia*	Merbatu	Chrysobalanaceae		IC
224	*Parkia javanica*	Kupang/Petai kerayong	Leguminosae		IC/ML
225	*Parkia speciosa*	Petai kerayong	Leguminosae		ML
226	*Payena lucida*	Nyatoh	Sapotaceae		ML
227	*Payena maingayi*	Nyatoh	Sapotaceae	Lower risk/least concern	IC
228	*Pentace laxiflora*	Takalis daun halus	Tiliaceae		IC
229	*Phyllocladus* sp.		Podocarpaceae		IC
230	*Pimelodendron griffithianum*	Perah ikan	Euphorbiaceae		ML
231	*Pinus carribea*	Pine	Pinaceae		ML
232	*Pittosporum ferrugineum*		Pitosporaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
233	*Ploiarium alternifolium*	Riang riang	Bonnetiaceae		ML
234	*Ploiarium* sp.	Riang riang	Bonnetiaceae		ML
235	*Podocarpus neriifolius*	Podo bukit	Podocarpaceae	Least concern	ML
236	*Podocarpus neriifolius*	Kayu china	Podocarpaceae	Lower risk/least concern	IC
237	*Polyalthia clauliflora*	Kerai larak	Annonaceae		IC
238	*Polyalthia rumphii*	Mempisang	Anonaceae		ML
239	*Polyalthia sumatrana*	Mempisang	Anonaceae		ML
240	*Popowia pisocarpa*	Mempisang	Annonaceae		ML
241	*Porterandia anisophylla*	Tinjau belukar	Rubiaceae		ML
242	*Pouteria malaccensis*	Nyatoh nangka kuning	Sapotaceae		ML
243	*Premna corymbosa*	Leban	Verbenaceae		ML
244	*Prunus* sp.1	Pepijat	Rosaceae		ML
245	*Prunus* sp.2	Stone fruits	Rosaceae		ML
246	*Pternandra coerulescens*	Sial menahun	Melastomataceae		ML
247	*Pternandra echinata*	Sial menahun	Melastomataceae		ML
248	*Pterospermum javanicum*	Bayur bukit	Malvaceae		ML
249	*Pterospermum* sp.	Bayur	Malvaceae		IC
250	*Randia scortechinii*	Tinjau belukar	Rubiaceae		ML
251	*Rapanea porteriana*		Myrcinaceae		ML
252	*Rennellia elliptica*	Tepejat	Rubiaceae		ML
253	*Rennellia speciosa*		Rubiaceae		IC
254	*Rhodamnia cinerea*	Mempoyan/poyan	Myrtaceae		ML
255	*Rinorea anguifera*	Sentil tembakau	Violaceae		ML
256	*Santiria griffithii*	Kedondong	Burseraceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
257	*Santiria laevigata*	Kerantai/Kedondong kerantai lichin	Burseraceae	Lower risk/least concern	IC/ML
258	*Santiria tomentosa*	Kerantai bulu	Burseraceae	Lower risk/least concern	IC
259	*Sapium baccatum*	Ludai	Euphorbiaceae		ML
260	*Saprosma* sp.		Rubiaceae		ML
261	*Saraca cauliflora*	Gapis	Leguminosae		ML
262	*Sarcotheca griffithii*	Belimbing pipi	Oxalidaceae		ML
263	*Scaphium linearicarpum*	Kembang semangkok bulat	Sterculiaceae		ML
264	*Scaphium macropodum*	Kembang semangkok jantung	Sterculiaceae	Lower risk/least concern	IC/ML
265	*Schefflera* sp.		Araliceae		IC
266	*Schima wallichii*	Gegatal	Theaceae		ML
267	*Schoutenia accrescens*	Bayur bukit	Tiliaceae		ML
268	*Scorodocarpus borneensis*	Bawang hutan	Olacaceae		IC
269	*Scutinanthe brunnea*	Kedondong sengkuang	Burseraceae	Lower risk/least concern	ML
270	*Shorea agentifolia*	Seraya daun emas	Dipterocarpaceae	Endangered	IC
271	*Shorea atrinervosa*	Selangan batu hitam	Dipterocarpaceae		IC
272	*Shorea ciliata*		Dipterocarpaceae	Endangered	IC
273	*Shorea curtisii*	Meranti seraya	Dipterocarpaceae	Lower risk/least concern	ML
274	*Shorea excelliptica*	Balau tembaga	Dipterocarpaceae		ML
275	*Shorea fallax*	Seraya daun kasar	Dipterocarpaceae		IC
276	*Shorea flaviflora*	Seraya daun besar	Dipterocarpaceae	Critically endangered	IC
277	*Shorea guiso*	Selangan batu merah	Dipterocarpaceae		IC
278	*Shorea johorensis*	Seraya majau	Dipterocarpaceae	Critically endangered	IC
279	*Shorea laevis*	Selangan batu kumus	Dipterocarpaceae	Lower risk/least concern/ ridges	IC

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
280	*Shorea leprosula*	Seraya tembaga/Meranti tembaga	Dipterocarpaceae	Endangered	IC/ML
281	*Shorea macroptera*	Meranti melantai	Dipterocarpaceae		ML
282	*Shorea Maxwelliana*	Selangan batu asam	Dipterocarpaceae	Endangered	IC
283	*Shorea microphylla*	Kawang jantung	Dipterocarpaceae		IC
284	*Shorea monticola*	Seraya gunung	Dipterocarpaceae	Endemic, mountains	IC
285	*Shorea multiflora*	Damar hitam pipit	Dipterocarpaceae		ML
286	*Shorea obscura*		Dipterocarpaceae	Hills	IC
287	*Shorea ovalis*	Meranti kepong	Dipterocarpaceae		ML
288	*Shorea ovata*	Seraya punai bukit	Dipterocarpaceae	Endangered	IC
289	*Shorea parvifolia*	Meranti sarang punai	Dipterocarpaceae		ML
290	*Shorea parvifolia*	Seraya punai	Dipterocarpaceae		IC
291	*Shorea parvistipulata*	Seraya lupa	Dipterocarpaceae		IC
292	*Shorea patoiensis*	Seraya kuning pinang	Dipterocarpaceae		IC
293	*Shorea pauciflora*	Meranti nemesu	Dipterocarpaceae	Endangered	ML
294	*Shorea platyclados*	Meranti bukit	Dipterocarpaceae	Endangered	ML
295	*Shorea* sp.	Seraya/Meranti	Dipterocarpaceae		IC/ML
296	*Sindora beccariana*	Sepetir	Leguminosae		IC
297	*Sindora coriacea*	Sepetir lichin	Leguminosae		ML
298	*Sindora echinocalyx*	Sepetir daun nipis	Leguminosae		IC
299	*Sloanea javanica*	Mendong	Lauraceae		IC
300	*Stemonurus malaccensis*	Katok	Icacinaceae		IC
301	*Sterculia parvifolia*	Kelumpang	Sterculiaceae		ML
302	*Streblus elongatus*	Tempinis	Moraceae		ML
303	*Swintonia* sp.	Merpauh	Anacardiaceae		ML

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
304	*Symplocos adenophylla*		Symplocaceae		ML
305	*Symplocos* sp.		Symplocaceae		ML
306	*Syzygium filiforme*	Kelat	Myrtaceae		ML
307	*Syzygium griffithii*	Kelat	Myrtaceae		ML
308	*Syzygium politum*	Kelat	Myrtaceae		ML
309	*Syzygium pustulatum*	Kelat	Myrtaceae		ML
310	*Syzygium* sp. 1	Kelat serai	Myrtaceae		ML
311	*Syzygium* sp. 1	Obah	Myrtaceae		IC
312	*Syzygium* sp. 2	Kelat	Myrtaceae		ML
313	*Syzygium* sp. 3	Obah	Myrtaceae		IC
314	*Syzygium* sp. 4	Obah	Myrtaceae		IC
315	*Syzygium* sp. 5	Kelat	Myrtaceae		ML
316	*Syzygium stapfianum*	Obah	Myrtaceae		IC
317	*Syzygium subdesugata*	Kelat	Myrtaceae		ML
318	*Tarenna* sp.		Rubiaceae		ML
319	*Terminalia* sp.	Telisai	Combretaceae		IC
320	*Ternstroemia tectandra*	Langkubak	Theaceae		IC
321	*Timonius wallichianus*	Kaum kopi	Rubiaceae		ML
322	*Trigonostemon malaccanus*		Euphorbiaceae		ML
323	*Tristaniopsis merguensis*	Pelawan	Myrtaceae		ML
324	*Tristaniopsis razakiana*	Pelawan	Myrtaceae		ML
325	*Tristaniopsis whiteana*	Pelawan	Myrtaceae		IC
326	*Urophyllum* sp.		Rubiaceae		ML
327	*Vatica dulitensis*	Resak bukit	Dipterocarpaceae		IC

No.	Scientific name	Local name	Family	IUCN Status/remarks	Location
328	*Vatica maingayi*	Resak daun merah	Dipterocarpaceae	Critically endangered	IC
329	*Vatica* sp.	Resak	Dipterocarpaceae		IC
330	*Vitex longisepala*	Leban	Verbenaceae		ML
331	*Vitex pinnata*	Leban	Verbanaceae		ML
332	*Vitex pubescence*	Leban	Verbanaceae		ML
333	*Vitex* sp. 1	Kulimpapa	Verbenaceae		IC
334	*Vitex* sp. 2	Kulimpapa	Verbenaceae		IC
335	*Weinmannia fraxinea*		Cunoniaceae		ML
336	*Xanthophyllum affine*	Minyak berok	Polygalaceae		IC
337	*Xanthophyllum eurhynchum*	Minyak berok	Polygalaceae		ML
338	*Xanthophyllum* sp.	Minyak berok	Polygalaceae		IC/ML
339	*Xerospermum noronhianum*	Rambutan pacat	Polygalaceae		ML
340	*Xylopia* sp.	Jangkang	Annonaceae		ML

IUCN International Union for Conservation of Nature, *ML* Mount Ledang, *IC* Imbak Canyon

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Chapter 20
Vegetation Diversity of the Russian Part of the Caucasus in the Era of Climate Change

Svetlana Litvinskaya and Ramazan Murtazaliev

20.1 Introduction

The Greater Caucasus (Bolshoy Kavkaz—the highest peak being Mount Elburz 5642 m) and the Lesser Caucasus (Maly Kavkaz—up to 4000 m) mountains in the north and south, respectively, are accepted as the historic barriers of these ranges (Ozturk et al. 1996a, b). The North Caucasus (Ciscaucasia) is the northern part of the region between the Black and Caspian seas within European Russia. It consists of Krasnador, Stavropol, and the constituent republics like Karachay-Cherkessia, Kabardino-Balkaria, North Ossetia-Alania, Ingushetia, Chechnya, and Dagestan extending from west to east. The fore-Caucasus steppe area is also put within the "North Caucasus"; thus, the northern boundary of the geographical region is generally considered to be the Kuma–Manych depression, bounded in the west by Azov Sea and the Straits of Kerch and by the Caspian Sea in the east. A major part of the Ciscaucasian region lies in Europe. It experiences a variable climate, with annual rainfall ranging from 150 mm in the eastern part of the hotspot on the Caspian coast—a semi-desert landscape known for its unique mud volcanoes—to more than 4000 mm in the coastal mountains along the Black Sea, where Georgia's Mtriala National Park houses a lush subtropical forest.

The extremes in altitude, broad variations in climate, and soil and vegetative conditions combine to form a wide range of landscapes in this region, from semi-desert to high-altitude tundra, from alpine meadow to deep forest, whereas the mountainous zones have peaks higher than any of the Alps.

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Geographically, the Caucasus region, encompassing the entire country of Georgia and parts of neighbouring Turkey, Russia, Armenia, and Azerbaijan, is accepted as one of the world's 25 biodiversity hotspots (Zazanashvili et al. 1999). Nearly one third of the flora comprising some 6400 species include 1600 endemics with a percentage endemism of 25 %, and is therefore of special conservation concern. Many of these endemics and rare, threatened, or vulnerable plants are at a risk of extinction if suitable measures are not adopoted for their protection as well as for the ecosystems they inhabit.

The vegetation of the region is also quite diverse. In the northern part of the hotspot, we come across a transition of grassland steppes to semi-desert ecosystems in the west, and then to desert in the east. In the central Transcaucasian Depression, swampy forests, steppes, and arid woodlands are replaced by semi-deserts and deserts along the Caspian Sea. The broad-leaved forests are a typical characteristic throughout the hotspot, together with montane coniferous forests and shrublands. There are two refugia of Tertiary flora in the region: the Colchis in the catchment basin of the Black Sea and the Hyrcanian in the extreme southeastern end of the Caucasus on the Caspian Sea coast.

The vegetative cover of the North Caucasus is notable for its complexity and originality. This is connected with the variety of physiographical conditions, the nearness of three seas, and the presence of latitudinal zonality and altitudinal belts. Flora and vegetation cover have passed a long evolutionary track of formation and disintegration of various types of floristic complexes. The histories of formation of the Caucasus as a mountain country are reflected in the glacial-age fluctuations reflected in its vegetation cover. This chapter presents studies undertaken on different plant associations of the North Caucasus. The description of vegetation types has been carried out with the help of classical geobotanical techniques. The studies start from the steppe and semi-desert regions of Ciscaucasia and go up to the alpine and subnival zones of the Great Caucasus.

20.2 Plant Diversity

The floral richness of the North Caucasus is noted for its surprising variety and originality. It includes approximately 1255 endemic species of the Caucasian region from which 338 are endemic for the Russian part of the Caucasus. In view of this unique characteristic nature, conservation activities are of paramount importance for the flora. Nearly 187 species are included in the "Red Book of Russian Federation" and 790 species are in the Red Data Books of the regions and other republics in its vicinity.

In West and Central Ciscaucasia, steppe vegetation once prevailed on the region's rich black soils, which now have been converted to agricultural land to a large extent. Forest–steppe vegetation, with oaks and beeches dominating the forest canopy, is found on the higher ground of the Stavropol Upland, around Mount Beshtau, in the western part of the Sunzha Range, and in the northern foothills of the Greater Caucasus. Eastern Ciscaucasia is semi-desert, with grasses and sagebrush (Artemisia) on the richer chestnut soils and saltworts where the soil is saline. Artemisia, saltworts, and ephemeral species characterise the arid Kura–Aras lowland, and similar vegetation occurs in the Middle Aras Trough. In the Colchic and Lankaran lowlands, the original subtropical broad-leaved forests have given way to cultivation.

At the lower elevations of the mountains, between 600 and 900 m, arboreal brushwood and broad-leaved forest predominate. On the Black Sea slopes of the Greater Caucasus and in the mountainous hinterland of the Colchic lowlands, there are mixed forests of beech, oak, hornbeam, chestnut, and alder, with lianas and an evergreen undergrowth on terra rossa and yellow soils.

20.3 Vegetation

The vegetative cover of the North Caucasus varies from the north to the south—from bottom of the mountains up to the nival belt, and from the west to the east—from the Prikubansky steppes to Peri-Caspian semi-deserts. A special position in the structure of the vegetative cover (Dolukhanov 1966) is taken by the southern macroslope of the northwest part of the Greater Caucasus where sub-Mediterranean and Colchic communities are distributed.

Ciscaucasia occupies an extensive territory where basically steppe and semi-desertic vegetation is interrupted at places by inundated forests and marshlands. Deserted landscapes are presented in the Tersko-Kumskaya lowland with two latitudinal zones adjoining each other as the zone of steppes and zone of deserts. Eastern Black Sea deserts with *Artemisia taurica* in combination with halophytic species are mostly spread in the basin of the river Kuma and lower reaches of Terek. Kumskiy sands stretch along the lower course of the river Kuma, Bazhiganskiy sands are near the Stavropol Territory, and Tereklinskiy sands turning into Terskiy sands are in the south. The structure of flora of Tersko-Kumskiy sands includes 450 plants (without ephemers; Bitkayeva and Nikolayev 2001). Peri-Caspian deserts are less widespread and presented by various xerophilous and haloxerophilous suffrutescent communities. *Artemisia lerheana* and *A. arenaria* with the participation of *Kochia prostrata* dominate in the first ones, and *Halocnemum strobilaceum* dominate in the second ones. Deserts occupy 300,000 ha of Tersko-Kumskaya lowland. Rare for the North Caucasus, relict *Erianthus ravennae* forms thickets in some areas, spreading out in the sands especially where underground waters come close to the surface, and *Imperata cylindrica* grows on dry weakly fixed sandy slopes of ridges and hillocks. Both species come from tropical areas. *Leymus racemosus, Isatis sabulosa, Artemisia marschalliana, Agriophyllum squarrosum, Senecio schischkinianus*, and *Asperula graveolens* flourish on open sands. On the ridges of barkhans, we observe *Melilotus arenarius* and *M. polonicus,* and in the blowing centres *Astragalus lehmannianus* is spreading.

In the low-lying part of the North Caucasus, there is an expressed belt of steppe vegetation in which intrazonal types of water–marsh complexes are interspersed. Overflow land is low lying, and eutrophic bogs are often covered with almost impassable thickets of hygrophilous bog–pratal vegetation. Formations of the overflown land are connected with the overflows of the rivers Kuban and Terek in spring and summer when the extensive spaces lie below the water level of the rivers and get flooded. The basic species on the mouth of river Kuban along the banks are *Phragmites australis, Typha angustifolia, Schoenoplectus lacustris, Butomus umbellatus, Alisma plantago-aquatica,* and some others. On the water surface, one can see *Nymphaea alba, Nuphar lutea, Salvinia natans, Trapa maeotica, Marsilea quadrifolia,* and *Nelumbo nucifera*. The underwater vegetation is presented by associations of *Potamogeton, Chara* sp., and *Zannikellia* sp. (Dubina and Shelyag-Sosonko 1989).

The area of the delta of the river Terek is 0.6 million ha (6000 km^2). Unlike the vegetation in the delta of the river Kuban, here big spaces are occupied by alkaline lands, which are connected with a recent outcome from under the sea surface. Reed thickets alternate with saline hollows and saltwort thickets, absinthial–gramineous semi-desertic communities, gramineous–forb meadow steppes, and thickets of bushes and lignosa lengthways riverbeds. Forests of delta of the river Terek are referred to as inundated or riparian woodlands. Their development is connected with proximity to subterranean waters. They have quite a poor floristic structure; only 38 species of woody shrubs grow here. Poplar stands (*Populus hybrida, P. nigra, P. tremula*), oak and elm–oak woods with *Ulmus suberosa,* and *Quercus robur* with admixture of *Populus nigra* and with undergrowth consisting of different kinds of bushes have a small-scale area of distribution.

In the delta of river Samur, there grows a unique lian–tugai lowland of subtropical wood with Hyrcanian elements and a considerable quantity of rare species. The vegetative cover of the lower reaches of Samur is amazing with its richness; 70 species of trees and bushes and more than 300 species of herbaceous plants (Novikova and Polyanskaya 1994) including 14 Tertiary relict species were observed here: *Prunus caspica, Vitis sylvestris, Pyrus caucasica, Acer laetum, Pterocarya pterocarpa, Hedera pastuchowii, Pyracantha coccinea, Alnus barbata,* and others (Yarovenko et al. 2004). The characteristic features of lowland forests in the Samur area are lianas. There are 15 species of these here: *Hedera pastuchowii, Vitis sylvestris, Periploca graeca, Smilax excelsa, Lonicera caprifolium, Humulus lupulus, Clematis vitalba, C. orientalis, Rubus* species, and others.

The utmost west of the North Caucasus Taman peninsula is singled out by its unique natural landscapes. There are mud volcanoes, saline lakes, sand spits, steppes, and overflow lands (Litvinskaya and Lozovoy 2005). The flora of the Taman peninsula includes 940 species of vascular plants. The vegetation is shrubby steppe where *Prunus spinosa, Amygdalus nana*, and *Rubus caesius* predominate. Typical steppe vegetation is found here with a fragmentary look and is presented by communities playing the role of edificators. These taxa are *Stipa capillata, Festuca valesiaca, Agropyrum pectinatum*, and *Koeleria cristata*. The floristic features of the area are the characteristic species: *Podospermum lachnostegium, Elitrigia tesquicola, E. stipifolla, Convolvulus tauricus*, and *Crambe steveniana*.

Along the sides of estuaries, in the environs of the Peresip–Turkish fountain, psammophilous steppes are common. Along the slopes of beams and hills, there are meadow steppes, on the saline soils—halophytic meadows with *Artemisia santonica, Limonium mejeri, Puccinellia distans,* and steppificated desert cenosis develop on the chestnut soils where *Artemisia taurica* and *Festuca valesiaca* act as edificators. *Tulipa biebersteiniana, Iris halophila, Iris pumila, Crambe steveniana, Gagea taurica,* and other species can be found among miscellaneous herbs.

The coastal zone of the Azov and Black seas of the peninsula is occupied by psammophilous littoral vegetation with peculiar species of *Glaucium flavum, Crambe maritima, Cakile euxina, Euphorbia paralias, Eryngium maritimum,* and others. Cenosis with prevalence of *Elymus sabulosus, Artemisia tschernieviana, Glycyrrhiza glabra, Eryngium maritimum, Ephedra distachia,* and *Crambe maritime* form the basic background of the vegetation.

The steppe vegetation of Ciscaucasia is highly varied and has a number of geographical features. The systematic structure of steppes flora is nonhomogeneous. So, floristic richness of the western Ciscaucasian steppes consists of 431 species. Bunch stipa–fescue steppes in Ciscaucasian calcareous chernozem soils occur in the Central Ciscaucasia on spurs of the Stavropol Elevation. Stipa–beard grass steppe, more mesophilic meadow steppes, and solonetzic meadows are also presented here. The basic edificators are the species of genus *Stipa* (*S. lessingiana, S. ucrainica, S. tirsa, S. capillata*) and also *Festuca valesiaca* and *Koeleria gracilis*. *Paeonia tenuifolia, Adonis vernalis, Iris notha, Salvia nutans, S. aethiopis, Phlomis pungens,* and others constitute the additional steppe herbaceous participants (Fig. 20.1). At some sites, one can observe steppe shrubs such as *Prunus stepposa, Amygdalus nana, Caragana molis, C. frutex,* and *Calophaca wolgarica*. The flora of the Stavropol Elevation includes 1404 species of higher plants (Ivanov 2002).

Fig. 20.1 Western Ciscaucasian steppes

There are practically no natural broad-leaved forests in this area; only small sites on the beams and valleys of the rivers are left back. Hornbeam forests, hornbeam–oak, oak–ash, and oak prevail all over, but seldom one can see the cenosis with participation of *Fagus orientalis* (Shiffers 1953).

In the East Ciscaucasia, in Peri-Caspian Dagestan, steppes give way to semi-desert. Gramineous–absinth and gramineous–kochia steppe communities with a domination of *Artemisia taurica, Onobrychis novopokrovskii, Puccinellia gigantea, Limonium meyeri, Tamarix ramosissima, Alhagi pseudoalhagi*, and others, and ephemer–absinth and gramineous–absinth communities with *Stipa capillata, Poa bulbosa, Festuca valesiaca, Agropyrum desertorum* and *A. pectinatum*, and *Kochia prostrata* develop here. Ephemer–gramineous–absinth communities with *Stipa lessingiana* and saltwort–absinth communities with *Limonium meyeri* and *Glycyrrhiza glabra* are common in the Peri-Caspian part of the Dagestan and the coastal strip of the Caspian Sea. The littoral zone of the Caspian Sea is covered with communities containing *Leymus racemosus, Convolvulus persicus, Melilotus caspicus*, and *Centaurea arenaria*. Halophilic vegetation of alkaline and saline soils expands within the Tersko-Sulakskaya lowland of the Dagestan. The basic species are *Salsola dendroides, Nitraria schoberi, Suaeda salsa, Psylliostachys spicata,* and others (Chilikina and Shiffers 1962; Fig. 20.2)

There is no sylvan vegetation in the plains of the East Ciscaucasia; small forest tracts consisting of *Quercus robur* have remained along the rivers Terek and Sulak. *Populus alba, Fraxinus excelsior,* and more rarely *Carpinus betulus* are mingled with oak; in the second layer, such species as *Salix, Ulmus*, and *Acer campestre* are evolving. *Viburnum opulus, Swida australis, Euonymus europaeus,* and *Rubus caesius* species of the genus *Crataegus* grow in the undergrowth. *Smilax excelsa, Vitis sylvestris, Humulus lupulus,* and *Periploca graeca* are common among lianas. In more damp places, ligneous vegetation of the tugai type is formed by thickets of *Salix* (*S. triandra, S. caspica, S. alba*) and *Populus alba* with the participation of *Elaeagnus angustifolia* and *Tamarix ramosissima* which is evolving.

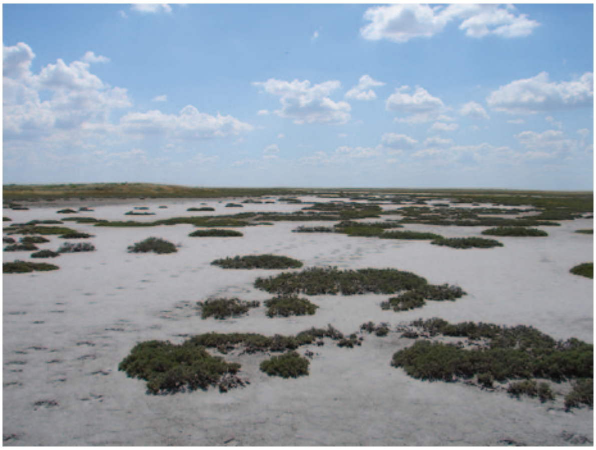

Fig. 20.2 Halophilic vegetation of alkaline and saline soils in the Tersko-Sulakskaya lowland of the Dagestan

The mountainous part of the North Caucasus changes greatly from the west to the east, and both species composition and peculiarity of zonal distribution of vegetation types differ sharply from each other. The *Kuban belt type* on the West Caucasus begins with a *bottom forest–steppe belt* up to 500–600 m above sea level. The climate is moderate continental. The average annual amount of precipitation is 660 mm. Under the conditions of plain relief, the shrubby steppe gramineous–herb meadows begin with shrubby steppes on compact chernozems. Higher on dark-grey mountain-forest soil, it transforms into woods consisting of *Quercus robur* with considerable intermixture of *Fraxinus excelsior, Populus tremula, Acer campestre*, and *A. tataricum*. Between the altitudes of 300 and 600 m above sea level on light grey mountain-forest soils, *Quercus robur* grows with considerable participation of *Carpinus betulus* and *Quercus petraea.*

Within the Central Caucasus, the bottom mountain belt begins with laccoliths of the Caucasian Mineral Waters, where there is a unique vegetation complex consisting of steppe, meadow–steppe, and not so often phryganoid flora. About 2300 species of higher plants have been registered here (Mikheyev 2000). In the bottom mountain belt of the Central and East Caucasus on abrupt slopes of terraces above the flood plain and calcareous ridges, there are stipa–beard grass steppes with *Stipa pulcherrima, Thymus pastoralis,* and *Astragalus bungeanus*. *Agropyron fragile* and *Kochia prostrata* dominate the herbaceous cover in the valleys of the rivers Urup and Zelenchuk, on Rocky and Cretaceous ridges in the vicinity of Mount Elbrus, on the slopes of the mountain Bermamut and mountains of the South Dagestan. Meadows and steppes of the bottom mountain belt have changed due to human activity; they are used as both summer and winter pastures and hayfields.

The *Dagestan belt type* in the bottom mountain belt is represented by steppes, sibljak, and scattered thickets of juniper stands. The altitude is 450–700 m above sea level. These are covered with forest–steppe where forest plots are interspersed in steppe communities. In the bottom mountain belt, steppe oak forests and oak light forests consisting of *Quercus pubescens* and *Q. petraea* grow on mountain-brown, dry stony eroded soils. On brown soils of northern slopes, *Quercus pubescens* forms oak groves where one can see *Acer campestre, Fraxinus excelsior, Ulmus suberosa,* and *Pyrus caucasica.* In more mesophytic communities, as undergrowth we find *Cornus mas, Prunus divaricata, Euonymus verrucosus, Ligustrum vulgare,* and *Lonicera caprifolium*; in more rarefied oak forests and light forests, there are species like *Crataegus, Rhamnus pallasii, Lonicera iberica, Spiraea hypericifolia*, and *Berberis vulgaris*. The grass cover in various associations of oak forests and light forests is also heterogeneous. Along with sylvan and meadow–steppe species here (*Poa nemoralis, Dactylis glomerata, Asparagus verticillatus, Anthriscus cerefolium, Origanum vulgare*), other steppe (*Festuca valesiaca, Phleum phleoides*) elements and hillside-xerophytic species (*Salvia canescens*) are quite frequent. Steppe oak forests are typical for the Central Caucasus.

There are pine–oak light forests growing on dry stony slopes starting from Sulak and further on to the east up to the Caspian Sea. The light forests consist of *Pinus kochiana, Quercus pubescens, Q. petraea, Juniperus oblonga, Sorbus graeca, Cotinus coggygria, Crataegus pentagyna, Celtis glabrata, Populus tremula, Rhamnus* *pallasii, Spiraea hypericifolia, Ephedra distachya, Cotoneaster racemiflorus,* and *Cerasus incana.* The grassy cover is rarefied and is formed exclusively by xerophytic species: *Teucrium polium, T. orientale, Carex pallescens, Centaurea squarrossa,* etc. The relict pinewoods grow locally here. Fragmental relict populations of *Betula pendula, Rhododendron luteum,* and *Amelanchier ovalis* are noted in their structure (Lepekhina 2002).

There are many original floristic complexes characterised by a rich variety of species and communities. Sand barchan Sarikum is a unique outlier occupying the bottom mountain zone. From here, 352 species of plants have been reported (Abachev 1995; Adgieva 1998). It is a rare psammophyte floristic complex with rare species (*Iris acutiloba, Astragalus karakugensis, Colchicum laetum*) and with considerable participation of turan elements (*Eremosparton aphyllum, Calligonum aphyllum, Astragalus lehmannianus*). There is no vegetation on the barchan top because of the constant movement of sands. On the slopes on blown sands, the first plants to appear are *Leymus racemosus, Artemisia tschernieviana, Calligonum aphyllum,* and *Carex colchica*. In the bottom part of the slopes, these species are joined by *Xeranthemum annuum, Syrenia siliculosa, Imperata cylindrica, Senecio schischkiniana, Jurinea ciscaucasica,* and *Kochia prostrata*. (Fig. 20.3).

Juniper light forests consisting of Juniperus polycarpos with participation of *Quercus pubescens, Celtis caucasica, Pyrus salicifolia, Rhus coriaria, Cotinus coggygria, Cerasus incana, Ephedra procera, Juniperus oblonga, Rhamnus pallasii, Cornus mas, Euonymus verrucosus, Berberis vulgaris,* and *Lonicera iberica* are an original floristic complex in Talgi. They are placed in the southern and north-eastern slopes. Juniper forests in Talgi are characterised by variety, diversity, and mosaic structure of their vegetative groupings, sparseness, and xerophytism of their cover. About 550 species of plants are distributed here in a small territory of ravine (Magomedova 2010a). Quite a large amount of mountain-xerophytic species and endemics (*Elytrigia gracillima, Stipa caucasica, Convolvulus ruprechtii, Reseda globulosa, Matthiola caspica, Salvia canescens, Crambe gibberosa, Astragalus alexandri*) make the herbaceous cover. Various types of juniper forests with participation of *Onobrychis cornuta, Spiraea, Artemisia,* etc. are marked out here (Lvov 1968; Magomedova 2010b).

Fig. 20.3 Barchan Sarikum with a rare psammophyte floristic complex

Fig. 20.4 *Astragalus utriger* Pall

The *Mediterranean (Crimean) belt type* is expressed on the southern macroslope in the northwest part of the Black Sea coast of the Caucasus. It is presented by absolutely other types of vegetation. The climate is arid subtropical (Mediterranean). Although this area concentrates Mediterranean hemixerophilous species, it is considerably impoverished with the Mediterranean flora (Fig. 20.4). It is noted for the presence of some genera which are lacking in the area of European deciduous woods but make the floristic kernel of the Mediterranean: *Achnatherum, Andrachne, Asphodeline, Colutea, Fibigia, Rhus, Vitex, Paliurus, Ruscus, Himantoglossum, Pistacia, Celtis, Ptilostemon,* and *Jasminum*. The bottom mountain belt begins with littoral vegetation; shrubby thickets consisting of *Paliurus spina-christi, Rhus coriaria,* and *Colutea cilicica*; and the maritime communities of *Pinus pityusa* (Litvinskaya 2004). In addition, there are hemixerophilous woods and xerophytic light forests occupying seaside ridges up to the height of 500 m above sea level. The climate is arid subtropical. Soils are soddy-calcareous, brown, and strongly eroded. The mountain seaside slopes up to the height of 200 m above sea level here are covered with woods consisting of relict endemic *Pinus pityusa* and relict *P. pallasiana*. Totally, forests consisting of Pitsunda pine occupy the area of about 1540 ha on the

Fig. 20.5 The light forests with *Juniperus excelsa* Willd., *J. foetidissima* Willd., *Pistacia mutica* Fisch. and Mey., and *Quercus pubescens* Willd

Black Sea coast. The floristic kernel of the formation is made up by the Mediterranean species: *Astragalus circassicus, Orchis simia, O. punctulata, Cephalanthera rubra, C. longifolia, Paeonia caucasica, Iris pumila,* and others.

At a high-altitude limit of 200–500 m is a strip of light forests of *Juniperus excelsa, J. foetidissima, Pistacia mutica, Quercus pubescens, Carpinus orientalis,* sibljak, and tomillares. In juniper light forests, the shrubby layer is formed by *Lonicera etrusca, Juniperus oxycedrus,* and *Jasminum fruticans* (Fig. 20.5). Among herbaceous species, there are a lot of local endemic species and other characteristic for the region of Crimea and Novorossiysk: *Dianthus acantolimonoides, Onosma polyphylla, Campanula komarovii, Potentilla sphenophylla, Himantoglossum caprinum*, and *Hedysarum candidum.* There are steppe tomillares in the West Caucasus that exist under the conditions of an arid Mediterranean climate. This is a peculiar type of vegetation where one can meet at maximum frequency representatives of family Labiatae: *Scutellaria, Teucrium, Salvia,* and *Thymus*. Tomillares embody not only endemic vicarious species but also local-specific endemics: *Thymus helendzhicus, Asperula taurica, Ptilostemon echinocephalus, Scutellaria novorossica,* and *Astragalus arnacanthoides*. Currently, tomillares are expanding their area due to human interferences.

On the southern macroslope in the southeastern part of the Black Sea coast, the *Colchic belt type* can be marked out. Climate is damp subtropical. The bottom mountain zone begins with littoral vegetation consisting of *Glaucium flavum, Eryngium maritimum, Euphorbia paralias, Medicago marina,* and xerophytic bushes (*Vitex agnus-castus, Paliurus spina-christi*). Subtropical Colchic forests consisting of *Castanea sativa, Quercus hartwissiana, Q. iberica, Fagus orientalis, Alnus barbata, Pterocarya pterocarpa, Ficus carica, Buxus colchica, Taxus baccata,* and others grow on zheltozem and zheltozem–podzolic soils at altitudes between 100 and 600 m above sea level. One can find beech trees at altitudes of 700–2100 m above sea level, but the belt of fir forests drops out here and is replaced by a beech–fir belt within an altitude of 1000–1200 m. Beech and fir are close in the bioecological relation and their areals adjoin. They form various mixed communities. Irrespective of the altitude above sea level and expositions of slopes, they grow on brown mountain-forest soils underlain by sandstones and clay slates. Fir–beech plantings are noted for their high efficiency. They may be fragmentarily met already in the basin of the river Chepsy, in the upper reaches of the river Verkhniy Defan, but they are more widespread in the southeast part of the southern macroslope. There are also subalpine and alpine meadows higher than beech–fir forests on the southern macroslope.

The vegetation of the *central mountain belt* is more homogeneous. The northern macroslope of the main Caucasian ridge is covered with broad-leaved woods. The total area of woods of the North Caucasus makes up 41,807,000 ha. Almost half of woods are concentrated in its western part within the West Caucasus, where 77 % of oak groves grow and more than one third of beech woods are found.

The *central wood belt* of the West Caucasus is dominated by oak and beech woods in complex with hornbeam and hornbeam–beech communities. It occupies altitudes from 600 to 1000 m above sea level where brown mountain-forest and brown mountain-forest podzolized soils prevail. The climate is moderate continental. The central mountain wood belt of the southeastern part of the Black Sea coast is presented by woods consisting of *Fagus orientalis*. Quite often, *Castanea sativa, Quercus iberica,* and *Acer platanus* are found with an evergreen undergrowth of *Laurocerasus officinalis, Ilex colchica,* and *Rhododendron ponticum*.

The *central mountain belt* in the northwestern part of the Black Sea coast of the Caucasus exists between the altitudes of 400 and 700 m above sea level and consists of woods made up of *Quercus petraea*. On watersheds (600–900 m above sea level), these extend after forest meadows and mountain steppes consisting of stipa–forb communities with hemixerophilous Mediterranean elements: *Thymus markhotensis, Salvia ringens, Asphodeline taurica, A. lutea, Sideritis euxina,* and *Teucrium chamaedrys* (Fig. 20.6).

Fig. 20.6 *Himantoglossum caprinum* (Bieb.) Spreng

The central mountain belt (500–700 m above sea level) is covered by oak woods consisting of *Quercus robur* and *Quercus petraea* in the Central Caucasus. Here, the woods consisting of *Quercus petraea* stretch along valleys and river slopes up to an altitude of 1000–1100 m above sea level, but on intramountain ridges on southern slopes they can be seen even higher (1800–2000 m above sea level), adjoining pinewoods. Durmast oak is joined by *Fraxinus excelsior, Acer campestre, A. platanoides, A. laetum,* and *Fagus orientalis,* and by *Cornus mas* and *Ligustrum vulgare* in undergrowth. Durmast oak occupies crests of hills and slopes of northern expositions. Prevernal ephemers and ephemeroids such as *Erythronium caucasicum, Helleborus caucasicus, Galanthus alpinus, Cyclamen coum, Ficaria verna,* and others develop from durmast oak in woods in the early spring. Rocky communities on cretaceous ridges of the central mountain belt are rather original within the Central Caucasus. A big number of ancient original endemic species such as *Saxifraga dinniki, S. columnaris, Charesia akinfievii, Campanula ossetica, Petrocoma hoefftiana,* and others can be seen here (Komzha 1991; Shagapsoyev 1994).

Beech woods grow at altitudes of 800–1200 m above sea level. They replace oak groves in height, are noted for their steady ecological areal, and occupy mainly wet and less often damp habitats on slopes of different expositions. The belt of beech woods in the North Caucasus begins in the west from the river Pshish (West Caucasus) and stretches to the east onto high mountains to the upper courses of the river Avar Koysu in Dagestan. Its high-altitude limits thus vary from 600 m above sea level in the northwest to 2000 m above sea level in Dagestan. The most productive forest stands of beech are formed within the heights of 700–1300 m above sea level. Beech woods floristically and coenotically come closer to Middle European ones but are allocated an independent position in the North Caucasian beech forests within the group of euxinic broad-leaved forests. The flora totals more than 400 species. The specific feature of beech woods is the abundance of relict species—derivatives of ancient Tertiary flora complexes. They are *Buxus colchica, Ruscus colchicus, Daphne pontica, Epimedium colchicum, Taxus baccata, Dioscorea caucasica, Vaccinium arctostaphylos, Laurocerasus officinalis, Ilex colchica*, and *Phyllitis scolopendrium*—totally, 68 species marked out in bioecological, coenotic, and floragenetic relations. Beech forms many vegetative communities from non-covered to compound with evergreen undergrowth and a rich herbaceous layer (Fig. 20.7).

There is no accurate border between the belts of beech and fir woods in the West Caucasus, though optimum conditions for beech develop at a height of 700–1300 m and for fir at a height of 1000–1600 m. On northern spurs of the main ridge, the beech woods belt drops out and mixed beech–fir communities prevail at heights of 1100–1400 m. They are replaced by pure fir forests higher along the slope. The decrease of the top border of pure beech forests from 1400–1500 m above sea-level to 1000–1100 m while approaching to the watershed ridge is noted in altitudes covered with beech.

Within the Central and East Caucasus in the central mountain belt, there are arid hollows where mountain-xerophytic vegetation develops. The flora of arid hollows of the Chechen and Ingush republics totals 1035 species: Dzheirahskaya

Fig. 20.7 Subtropical Colchic forests with *Buxus colchica* Pojark., *Taxus bacata* L

hollow—856 species, Targimskaya—930 species, and Itumkalinskaya—902 species (Taisumov et al. 2011).

Mountain-xerophytic vegetation is especially dominantly expressed in Central Dagestan, where microevolutionary processes proceeded intensively as a result of long isolation, peculiar features of mountain-forming process, complexities of relief, and general climatic aridity. Almost each systematic group here has endemic species, many of which are narrowly local. More than 900 endemic species of Caucasus plants are reported from the northern macroslope of East Caucasus (Murtazaliev and Litvinskaya 2009). This makes 72.35 % of all Caucasus endemics noted in the Russian part (Litvinskaya and Murtazaliev 2009). The fact of the presence of three monotypic endemic genera (*Muehlenbergella, Pseudobetckea,* and *Mandenovia*) here stresses the antiquity and intensity of the speciation process. These are isolated and highly specialized genera having weakly outlined links and extremely seldom ranged.

Fig. 20.8 *Tanacetum akinfievii* (Alexeenko) Tzvel

The origin of more than half of endemics in East Caucasus is connected with Central Dagestan (Fig. 20.8), many of which do not fall outside the bounds of this area: *Allium mirzojevii, A. gunibicum, Astragalus fissuralis, A. daghestanicus, Centaurea awarica, Seseli alexeenkoi*, *Scabiosa gumbetica, Tanacetum akinfievii, Medicago gunibica,* and many others (Murtazaliev 2012).

The whole Central Dagestan is presented by mountainous-xerophytic vegetation and at places one can meet pine and birch–pinewoods on northern slopes. There are almost no woods in South Dagestan and their places are occupied by steppe meadows or thickets of bushes on spots and small sites of wood. A typical feature of the Dagestan belt type is that in comparison with West and Central Caucasus belts it shifts upwards almost up to 1000 m, and on spots even up to 1500 m, which is connected with the general aridity of the climate.

Beech, beech–fir (from 1100 to 1400 m above sea level) dark coniferous (*Abies nordmanniana, Picea orientalis*) forests occupy the territory of the *high-mountain wood belt* within the borders of the West Caucasus on brown mountain-wood podzolized soils within the heights of 1400 m and up to 1800 m above sea level. If the belts of beech and fir woods are expressed on the northern macroslope, the *Fagus orientalis* belt is replaced by beech–fir woods at a height of 900–1700 m above sea-level *Colchic belt type*.

Basic tracts of *Abies nordmanniana* are concentrated in the basins of the rivers of Psheha, Malaya, and Bolshaya Laba and fray out in the upper reaches of the river Kuban. The farthest eastern growth place on the northern macroslope of the Greater Caucasus is the basin of the river Terek alongside the river Tutunsu. A total of 217 species referring to 139 genera and 70 families have been recorded in the formational flora of *Abies nordmanniana* and *Picea orientalis*. In the herbaceous layer of these communities, usually *Asperula odorata, Oxalis acetosella, Calamintha grandiflora, Daphne mezereum, Dentaria bulbifera, Sanicula europaea, Geranium robertianum, Myosotis amoena, Rubus caucasicus, Paris incompleta, Sambucus ebulus, Polygonatum polyantherum, Festuca drymeja, Euphorbia macroceras, Gentiana schistocalyx, Senecio platyphylloides, Viola reichenbachiana,* and ferns—*Athyrium filix-femina, Dryopteris filix-mas,* and others flourish.

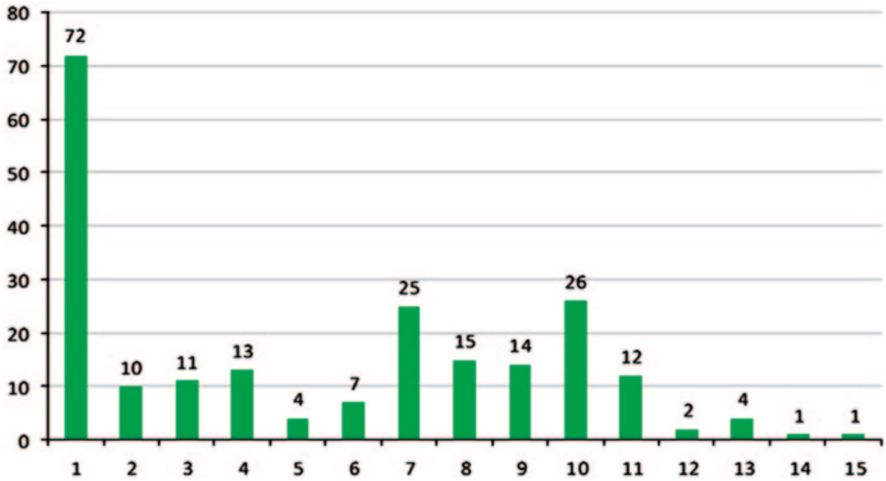

Fig. 20.9 Structure of dark coniferous forests according to the belt type. (Note: *1* bottom mountain-central mountain; *2* high mountain wood; *3* bottom mountain; *4* central mountain; *5* high mountain wood-alpine; *6* central mountain-subalpine; *7* bottom mountain—high mountain; *8* high mountain wood - subalpine; *9* subalpine, alpine; *10* central mountain—high mountain wood; *11* subalpine; *12* bottom mountain—alpine; *13* bottom mountain—subalpine; *14* alpine; *15* central mountainalpine

Belt-type ecological analysis of dark coniferous forest flora reveals that the basic quantity of species coincides with the bottom mountain–central mountain belt (72 species); with the central mountain–high-mountain wood belt—26 species; from bottom mountain to high-mountain wood belt—25 species; high-mountain wood–subalpine (15 species); subalpine–alpine (14 kinds); central mountain (13 species); subalpine (12 species); bottom mountain (11 species); high-mountain wood (10 species); central mountain–subalpine (7 species); high-mountain wood–alpine (4 species); bottom mountain–subalpine (4 species); bottom mountain-alpine (2 species); alpine (1 species); and central mountain–alpine—1 species (Fig. 20.9).

Beech and birch forests replace the belt of fir woods and communities consisting of *Pinus kochiana* dominating southern slopes and rocky sites.

Within the territory of Central and East Caucasus at an altitude of 1400–1800 m above sea level, there are broad-leaved forests consisting of *Carpinus betulus* and *Fagus orientalis,* to which the species of *Betula, Acer, Alnus, Ulmus, Tilia,* and others mix up. Considerable participation is taken by *Pinus kochiana*. There are other wood–shrub species seen here: *Corylus avellana, Quercus macranthera, Fraxinus excelsior, Salix caprea, Tilia cordata, Populus tremula,* etc. The undergrowth consists of sporadic species of the bushes: *Lonicera xylosteum, Daphne mezereum, Rosa oxyodon, Viburnum opulus, Euonymus verrucosus,* and some others. Characteristic herbaceous plants of these woods are: *Aquilegia olympica, Sanicula europaea, Oxalis acetosella, Asperula odorata, Valeriana tiliaefolia, Astrantia biebersteinii, Primula macrocalyx, Salvia glutinosa,* etc.

The belt of high-mountainous vegetation is characterised by alternation of subalpine forests, thickets of *Caucasian rhododendrons,* tall herbaceous cover, and subalpine and alpine meadows. It occupies the limits of heights from 1700 to 2700 m above sea level. There are three strips marked out: subalpine beech and fir forests at a height of 1700–1800 m (sometimes rising up to 2000 m), thickets of Caucasian rhododendrons on peaty soil, and tall herbaceous cover; a strip of subalpine meadows at a height of 1500–2300 m on mountain-meadow soils in a complex with vegetation of rocks and taluses; and subalpine communities combined on spots with alpine meadows. Birch forests occupy a strip 100–150 m above fir–beech woods.

In the West Caucasus, subalpine birch forests grow in the upper courses of the rivers Belaya and Psheha, in the vicinity of Krasnaya Polyana, on the mountain Achishho. They are noted for their rich floristic composition and abundance of Caucasian species. Species peculiar to the high-mountain belt are subalpine tall herbaceous cover; subalpine and alpine meadows grow in the herbaceous layer. Under the birch crown layer, one can find *Geranium sylvaticum, Delphinium dasycarpum, Anemone fasciculata, Polygonatum verticillatum,* and *Festuca soommieri*. Beech–birch forest with the underbrush consisting of *Rhododendron caucasicum* develops on the upper reaches of Teberda. The pine–birch forest belt consists of *Betula litwinowii, B. pendula,* and *Pinus kochiana* is expressed in the Central Caucasus.

Further on to the East above 1700–1800 m, pinewoods are gradually replaced by birch woods where the greater part is taken by *Sorbus aucuparia, Salix caprea, Quercus macranthera, Fraxinus excelsior,* and *Populus tremula.* At the upper limit, birch forest stands turn into crooked forests and form various combinations with the thickets of *Rhododendron caucasicum*. Sometimes, small undershrubs *Vaccinium myrtillus, V. vitis-idaea,* and *Empetrum caucasica* join them.

High-mountain maple forests consisting of *Acer trautvetteri* are quite original at an altitude of 1800–2200 m above sea level. Representatives of subalpine tall herbaceous cover (*Gadelia lactiflora, Cephalaria gigantea, Symphytum asperum, Telekia speciosa, Delphinium speciosum, D. pyramidatum, Aconitum orientale, Heracleum mantegazzianum,* and others) are considerably developed here.

Subalpine vegetation is a compound complex of various types located between the top border of wood and alpine meadows belt, in woodless areas—between the top border of mountain steppes and the belt of alpine meadows and mats. Subalpine vegetation occupies the area from the top border of closed wood coniferous and broad-leaved communities to the bottom border of alpine belt.

The structure of subalpine meadows is motley. The basic dominating species here are *Bromopsis variegata, Festuca woronowii, Milium schmidtianum, Arrhenatherum elatius,* and *Calamagrostis arundinacea*; the following motley grass species are usual *Anemone fasciculata, Pedicularis atropurpurea, Geranium ruprechtii, Aquilegia olympica, Lilium kesselringianum, Scabiosa caucasica*, and *Verbascum wilhelmsianum* (Fig. 20.10). Thickets of *Rhododendron caucasica, Juniperus hemisphaerica, J. sabina, Vaccinium vitis-idaea, Empetrum caucasicum, Salix caprea*, and *S. kazbekensis* are interspersed into subalpine meadow vegetation. *Rhododendron caucasicum* formation is the ancient type of vegetation widespread in the east from the mountain Oshten and stretching to the riverhead of Samur in

Fig. 20.10 Scabiosa caucasica M. Bieb.

Dagestan. They develop on peaty soil. They are floristically poor and are weakly dismembered into communities.

The strip of alpine meadows stretches at an altitude of about 1800–2100 m in the west and 2300–2800 m and 3300 (3700) m above sea level in the Central and East Caucasus. Alpine meadows are close to subalpine ones, but they are undersized and composed of firm bunchgrass and high-mountainous sedges, widespread across the whole Greater Caucasus and represented by various sorts of communities: miscellaneous herbs and Gramineae. *Colpodium versicolor, Crocus scharojanii, Polygala alpicola, Pedicularis ochrorrhyncha, Briza marcowiczii, Alopecurus ponticus, Kobresia schoenoides*, and *K. capillifolia* are common here.

A special place in the alpine belt of the North Caucasus is taken by alpine mats, characterised by weak occurrence of Gramineae and sedge, but with the great species variety in miscellaneous herbs among which *Campanula biebersteiniana, Primula algida,* species of *Potentilla, Alchemilla,* and other species are often met (Fig. 20.11).

Fig. 20.11 Alpine belt of the North Caucasus

Though in whole the floristic structure of alpine mats is poorer than those of other types of high-mountainous vegetation, Gramineae–forb and forb mats with *Crocus vallicola, Pedicularis nordmanniana, Euphrasia alboffii,* and *Euphrasia amblyodonta* are the most widespread in the West Caucasus. Ranunculaceous mats consisting of *Ranunculus helenae* are registered on the slopes of Fisht.

These meadows become drier to the east and rise upwards to 3000 m and higher. Thickets of undershrubs and bushes are frequent in the alpine belt. There is a great number of rocks, slide rocks, placers, and moraines with rocky and slide-rocky vegetation where there are many endemic species: *Lamium tomentosum, Veronica minuta, Delphinium caucasicum, Thymus majkopensis, Ziziphora subnivalis, Astragalus bachmarensis,* and *Hypericum nummularioides* in the alpine belt of the Greater Caucasus. Increased localisation of rare endemics of the Caucasian origin is marked here. It is the ancient centre of speciation. The existence and duration of rocky and slide-rocky substrates and also isolation promote specific endemic species development. They are *Daphne circassica, Betonica abchasica, Gypsophila steupii,* and some others in the West Caucasus. There are many endemic species of genus *Campanula, Jurinea,* and others in this belt of the Central Caucasus (Fig. 20.12).

High-mountainous tundra—the heathlands presented by moss–lichen communities with separate species of plants inclusion (Fig. 20.13)—are spread on the most raised places, on moraines at a height of 2700–3000 m within the West and the Central Caucasus, and up to 4000 m above sea level in the East Caucasus.

In the Central Caucasus in high mountains under favourable hydro-geological conditions of cols and lake glacial expansions, it is possible to find high-mountainous bogs: sedge-cotton grass, marshy sege meadows with well-expressed hypnum-moss cover.

Rocky and slide-rocky vegetation of the East Caucasus (on the massifs Snegovoy, Bogosskiy, Nukatl, Samurskiy, Hultay-dag, etc.) has open cover and consists of *Saxifraga caspica, Draba bryoides, Campanula argunensis, Pseudovesicaria digitata, Ranunculus arachnoideus, Nonnea daghestanica, Arabis farinacea, Valeriana daghestanica, Vavilovia formosa, Viola minuta, Trisetum transcaucasicum, Nepeta supina, Pseudobetckea caucasica, Veronica bogosensis,* and others.

Fig. 20.12 Rocky of the Central Caucasus

Fig. 20.13 High-mountainous tundra

Rather interesting and original is the flora of calcareous mountains of Shalbuz-dag and Yaridag and also the bordering mountain Shahdag in Azerbaijan where their own local endemics (*Dianthus vladimiri, Astragalus eugenii, A. beckerianus,* and others) and some high-mountainous Iranian elements such as *Didymophysa aucheri, Tanacetum kotschyi, Cicer minutum,* and others can be found.

20.4 Climate Change and a Unique, Threatened Plant Diversity

The Caucasus is biologically one of the richest regions on our planet. It is home to an unusually high number of endemics and is accepted as one of the world's biodiversity "hotspots" (Zazanashvili et al. 1999), with a diversity greatest of any temperate forest region in the world.

The Caucasus ecoregion is located on the biological crossroads, where plants from Europe, Central Asia, the Middle East, and North Africa mix with endemics absent in other corners of earth (Parks and Ozturk 1992). The hotspot spans 500,000 km^2 including Georgia, Azerbaijan, Armenia, small parts of Russia, Turkey, and Iran. The relatively small area is made up of varying landscapes from semi-desert to high-altitude tundra, from alpine meadow to deep forest. There are over 6000 species of vascular plants, and approximately more than 1500 are unique to this region. Nearly 17 genera are endemic to this region, out of these 9 are associated with the high-altitude ecosystems. About 80 % of the plants occupying Colchic limestone scree grow only here in the world. There are many ancient species like endemic rhododendrons (*Rhododendron caucasicum, R. ungernii, R. smirnowii*) and Persian ironwood (*Parrotia persica*). A large number of plants are economically important, such as wild crop relatives like wheat, rye, and barley, as well as nuts and fruits like walnuts, apricots, and apples (Gagnidze et al. 2002).

The region has been inhabited and affected by humans for tens of thousands of years and on ab average basis nearly 50 % of the land in the region has already been transformed by human activities. However, there are still many pristine areas in the hotspot, mostly in remote high-altitude areas and inaccessible gorges. Approximately 145,000 $km^2$of the land is still a natural habitat and 12 % of the original vegetation can be regarded as pristine

The diversity here is losing the race at an alarming rate. About 50 % of the lands in this ecoregion as well as large areas in the neighbouring states have changed due to human interferences (Ozturk 1995; Ozturk et al. 1991, 2010). The most degraded are the plains, foothills, and subalpine belts. The majority of the natural old growth forests have been fragmented into small sections, divided by areas of commercial forests, and agricultural and developed lands, and less than 12 % of the original vegetation, including forests, can be considered pristine.

Major threats to the plant diversity in this ecoregion are the same as in the Mediterranean and the Black Sea region of Turkey (Ozturk et al. 1997, 1998) and include illegal logging, fuel wood harvesting, and the timber trade; overgrazing; poaching and the illegal wildlife trade; infrastructure development; and pollution of rivers and wetlands. Overgrazing has eroded the natural vegetation in more than 30 % of subalpine and alpine summer ranges and about 50 % in the winter ranges of the steppe and semi-desert areas. These threats lead to habitat degradation, decrease in the species population, and disruption of ecological continuity. The conservation situation has deteriorated due to social and economic crises and climate change is adding to these degradative forces.

Concluding Remarks

Currently, protected areas cover roughly 44,000 km^2 which equals 8 % of the region's total land area; 39,000 km^2 of this (7.3 %) is in protected areas in the International Union for Conservation of Nature (IUCN) categories I–IV. More of the remaining habitat in the Caucasus hotspot needs to be formally protected to ensure the long-term survival of the plant diversity.

Trans-boundary projects are important conservation priorities in the region for connecting populations of wide-ranging species in the region's fragmented habitats, as well as for protecting threatened and endemic species. More than 2000 glaciers are found here which cover an area of 1450 km^2in the Greater Caucasus range. The northern third of the hotspot is the broad North Caucasus Plain, the eastern part of which is below sea level. Any change in the temperatures will defintely have devastating effects.

Several NGO agencies are working in the Caucasus on nature conservation and environmental education projects, but still there is a long way to go.

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Chapter 21
The Effects of Climate Change on Avian Diversity in High-Altitude Wetland Habitats

Muhammad Nawaz Rajpar and Mohamed Zakaria

21.1 Introduction

Climate change is emerging as perhaps the greatest environmental challenge of the twenty-first century. The temperature of the earth is rising due to human-induced factors and natural processes which may cause global warming that abruptly affects diverse habitats (such as wetlands, forests, rangelands, etc.) and avian community structures directly or indirectly. Climate change may ultimately cause a shift in home range, reduced food resources, changed breeding behavior, increased risk of predation, and extinction of various avian species. Human beings are a major cause of climate change that has ultimately increased the risk of extinction of waterbird species as well as their habitats. Climate change is one of the gravest threats facing waterbirds today; waterbird species in various countries are in real danger due to rise and fall in temperature and precipitation, which may have affected the wetland habitat structure, food resources, and reproductive success that has ultimately reduced their home range, habitat suitability, and food resources. Determining the effects of climate change on avian diversity and their habitats provides information how climatic factors such as temperature and precipitation affect bird community structures and habitats in high-altitude wetlands and what changes will occur due to climate change. Thus, it also helps in better conservation and management of avian diversity in high-altitude wetlands in future.

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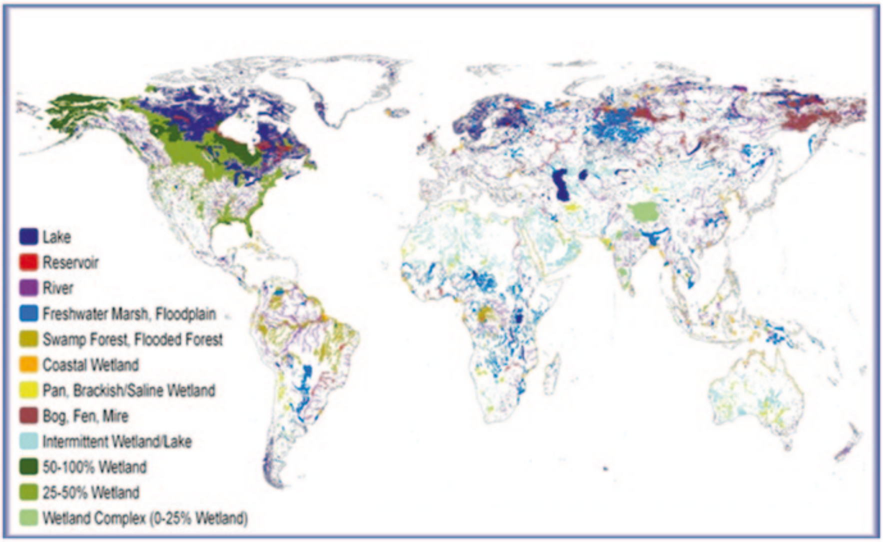

Fig. 21.1 Map of the world's wetland areas (Lehner and Doll 2004)

Fig. 21.2 Wetland habitat used by a wide array of migrant bird species

21.2 Wetland as a Habitat for Avian Species

Wetlands are characterized by shallow water overlying waterlogged soil, interspersed submerged and emergent aquatic vegetation such as emergent, submerged, reedbeds, and grasses (Zhang et al. 2010). The total area of the world's wetlands range between 5.3 and 12.8 million km^2 (Zedler and Kercher 2005; Panigrahy et al. 2012). It is estimated that almost 86% of the world's wetland areas are found in tropical, subtropical, and boreal regions, while the remaining 14% are found in temperate zones.

Wetland habitat is a distinctive set of physical environmental factors that bird species use for its survival and reproduction. The habitat of birds is not solely comprised of vegetation but also a combination of biotic and abiotic factors that influence the level of use and availability of food resources. Birds are an important component of wetland ecosystems (Fig. 21.2) and often exhibit distinct relationship with their habitats and food resources (Seymour and Simmons 2008). Naugle et al. (2001) reported that wetlands provide suitable habitats for breeding and foraging for more than one quarter of the regional avifauna and most of them are nongame species. For example, various globally threatened (i.e., Storm's stork—*Ciconia stromi,* Spotted Greenshank—*Tringa guttifer,* Chinese Egret—*Egretta eulophotes,* Milky Stork—*Mycteria cinerea,* Lesser Adjutant—*Lepotilos javanicus,* and Spoon-billed Sandpiper—*Euryorhynchus pygmeus*) and non-threatened bird species depend on wetlands to fulfill their daily requirements, such as food, water, and shelter (Stumpf and Haines 1998; Dierschke et al. 1999; Aik et al. 2002; Ishikawa et al. 2003; Fig. 21.1).

Wetlands are the most productive ecosystems due to habitat diversity and richness of food resources, i.e., fish, amphibians, reptiles, and invertebrates (Rajpar et al. 2010; Haber 2011). The diversity of vegetation and food resources are major driving factors, which play a significant role in attracting diverse bird species and indicate where and how they use a particular habitat. The distribution and diversity of wetland-dependent bird species is influenced by vegetation structures and composition, richness of food resources, occurrence of surrounded landscapes, and protection from predators and harsh weather. They often select a habitat, which offers a wide array of microhabitats, diversity of food resources, safe breeding grounds from predators and harsh weather.

21.3 Tangible and Intangible Benefits of Wetland Ecosystems

Having mentioned that wetland ecosystems provide diverse tangible and intangible benefits on a sustainable basis (Zedler and Kercher 2005; Sharma and Rawat 2009) to human beings, i.e., water supply, trapping of raw materials and nutrients, food, flood control, and recreation to humans (Hansson et al. 2005) as well as for wildlife species in terms of food and habitat. Apart from concrete products, wetlands also play an important role in recharging the water table and balancing the water cycle. Their specific role is rainwater storage, water regulation, i.e., ground water recharge and discharge (hydrological flows, water purification, i.e., retention, recovery, and removal of excess nutrients and other pollutants), and erosion control (i.e., retention of soil sediments and accumulation of organic matter).

In developing countries, most often the local communities directly or indirectly depend on a variety of wetland products such as food (fishes, medicinal plants, grains, fruits, and bushmeat). In addition, apart from providing habitats and food sources, wetlands also support commercial and recreational fisheries by providing nursery habitats and delivering several direct and indirect services to local communities (Clynick and Chapman 2002; Ansari et al. 2003). Wetlands also accommodate other human needs, such as water supply and navigation. Moreover, they serve as a barrier for flood control if they are located near an area of potential damage.

The use and importance of high-altitude wetlands may vary from place to place depending on human perceptions (i.e., culture), occurrence of wildlife species, and other products. Productive and spatially diverse wetlands fulfill many important functions, namely (1) habitat for birds, fish, amphibians, reptiles, mammals, and aquatic invertebrates; (2) water for domestic, industrial and agricultural uses; (3) fiber and fuel, i.e., logs, fuel wood, peat, and fodder (4) resources for biochemicals, i.e., the extraction of medicines and other materials from biota; (5) resources for genetic materials, i.e., genes for resistance to plant pathogens, ornamental species, and others; (6) regulating climate, i.e., source and sink of greenhouse gases; (7) influence local and regional temperature, precipitation, and other climatic processes; (8) education, i.e., opportunities for formal and informal education and training; and (9) nutrient cycling, i.e., storage, recycling, processing, and acquisition of nutrients. Furthermore, many religions also attach spiritual and religious values to aspects of wetland ecosystems, i.e., the source of inspiration (Constanza et al. 1997; Nakamura et al. 1997; Messina and Connor 1998; Stumpf and Haines 1998; Dierschke et al. 1999; Ishikawa et al. 2003).

21.4 Threats to Wetlands

Natural habitats of avian species have been destroyed by various human-induced factors as well as natural processes. Evidence shows that around 50 % wetland areas of the world have been lost in the past century and their destruction still continues in all countries (Turner et al. 2000; Froneman et al. 2001; Mitsch and Day 2006). It has also been reported that we have irreversibly lost 95 km^2/year-wetland area (a great resource of life) during mid-1980s to the early 2000s due to human intervention (Coleman et al. 2008). It has been reported that 20 % of waterbird species, 30 % of mammal species (i.e., dolphins, manatees, and porpoises), 20 % of freshwater fish species, 30 % of amphibians, 50 % of turtles, and 45 % of crocodile species populations have declined due to wetland habitat loss (Zavagali 2009).

Wetlands are continuously threatened in almost all developed and developing countries in a variety of ways. The major driving factors of destruction of the world's wetlands are: diversion and damping of river flows, conversion of wetlands into agriculture fields and aquaculture ponds, development of housing societies, disconnection of floodplains due to construction of dams and roads, eutrophication, contamination of water due to runoff from agricultural fields, pollutant effluents from industries, over grazing and harvesting of flora and fauna, and invasion of invasive (exotic) species that have caused patchiness (Larson 1995; Van Vessen et al. 1997; Bernert et al. 1999; Brinson and Malvarez 2002). These factors pose a serious threat as they deliberately reduce and disperse many important wetland areas in the world, causing degradation and habitat loss. Consequently, the gradual loss and degradation of wetland areas have adversely affected avian species that fully depend on wetland habitats for their survival (Gillespie 2007; Mitsch 2010). It has been reported that the population of many migrant bird species have declined worldwide due to loss of important stopover habitats (i.e., high-altitude wetlands) in mid-continental regions (Harrington et al. 2002; Stutzman 2012).

Many wetlands, which are important habitats for avian species, are under heavy pressure and are at risk due to degradation and habitat loss (Botkin et al. 2007;

Fig. 21.3 Aesthetic view of a high-altitude wetland ecosystem

Fischer and Lindenmayer 2007). These consequently cause degradation of breeding sites, water level stabilization, sedimentation, contaminant and nutrient inputs, and invasion of exotic plants and animals (Parish et al. 1987; Scott and Poole 1989; Davidson and Rothwell 1993). In addition, gradual losses of wetlands are considered to be responsible for population decline in many species, such as golden plovers—*Pluvialis apricaria,* snipes—*Gallinago gallinago,* dunlins—*Calidris alpine,* godwits—*Limosa limosa,* and lapwings—*Vanellus vanellus* (Beintema and Saari 1997; Schekkerman and Müskens 2000; Altman and Bar 2001; Stroud et al. 2004; Taylor and Pollard 2008).

21.5 High-Altitude Wetlands

Nature has bestowed high-altitude regions with plenty of natural resources, out of which wetlands are one of the fragile and highly productive ecosystems (Fig. 21.3). In high-altitude regions, all wetlands are fed by glacial melt in the form of springs and streams originating from the immediate catchments. During summers (July–August), water level in these wetland habitats rises while in winters (November–December) it falls to its minimum level. These wetland areas are rich in biological diversity where a number of flora and fauna are found.

High-altitude wetlands are aquatic habitats which occur in the higher reaches of mountains above 3000 m (Chatterjee et al. 2010; Jayachandran 2013) and constitute an integral part of the water table recharge and habitat of the wide array of avian species. High-altitude wetlands support a higher biological diversity (treasure trove) and are important stopovers for migratory birds during arrival and departure of migration periods (Sherub 2004). These wetlands encompass swamps, marshes, meadows, fens, peatlands, streams, dams, reservoirs, and lakes. They are rich in aquatic vegetation such as pond water crowfoot—*Ranunculus trichophyllus,* water weed—*Hydrilla verticillata,* curly-leaf pondweed—*Potamogeton crispus,* sweet flag—*Acorus calamus,* grassy-leaved sweet flag/Japanese rush—*A. grimineus,*

Fig. 21.4 High-altitude wetlands are a major source of water for millions of people and rivers, and are the most biologically diverse aquatic ecosystems

Fig. 21.5 Migratory waterbird species utilize wetland habitat during winter

hard-stemmed bulrush—*Shoenoplectus juncoides,* common reed—*Phragmites spp.,* horsetail rush—*Equisetum spp.,* alpine smart weed—*Aconogonon alpinum,* swamp sedge—*Carex spp.,* and spreading rush—*Juncus spp.* The availability of food resources of wetlands, mainly related to richness of vegetation and productivity of detritus.

High-altitude wetlands are a major source of water for millions of people and rivers, and are the most biologically diverse aquatic ecosystems (Fig. 21.4). Not only are they sources of water but they also serve as a suitable habitat and breeding ground for a wide array of residents as well as migrant bird species (Table 21.1) such as northern pintail—*Anas acuta,* Eurasian teal or common teal—*A. creca,* northern shoveler—*A. clypeata,* Eurasian coot—*Fulica atra,* mallard—*A. platyrhynchos,* red-breasted merganser—*Mergus serrator,* yellow wagtail—*Motacillla flava,* brown dipper—*Cinclus pallasii,* and grey heron—*Andrea cinerea* in autumn (October–December) and spring (March–April; Figs. 21.5 and 21.6). High-altitude wetlands are important habitats (stopovers) for migrant bird species, i.e., they replenish their energy reserve en route to the final destination from these habitats (McGrath et al. 2009) (Fig. 21.7).

In addition, terrestrial birds such as golden eagle—*Aquila chrysaetos,* peregrine falcon—*Falco peregrinus,* etc., also use these wetland habitats in search of food. These species migrate from their native habitat to temperate wetland ecosystems due to severe winter. They fly over the high-altitude wetland areas during their

Fig. 21.6 Waterfowl flying over wetland habitat

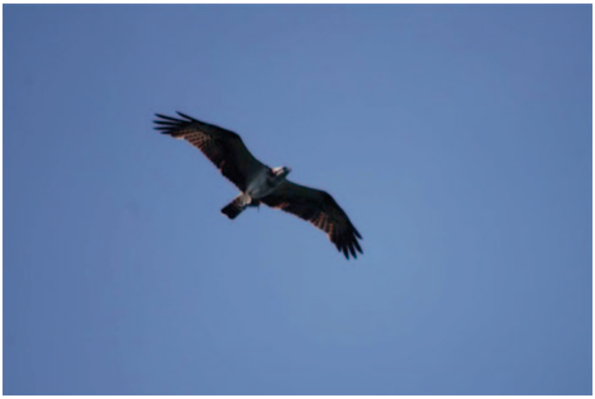

Fig. 21.7 Osprey flying over wetland

flight to warmer places and utilize these wetland areas as a stopover. These wetlands are rich and diverse in food and microhabitat resources (Both and Visser 2001; King and Finch 2013).

21.6 Effects of Climate Change on Wetlands and Bird Species

Climate change has significantly affected wetland habitat characteristics which influence avian community structures such as home range, relative abundance, reproduction, and behavior (Parmesan and Yohe 2002; Parmesan 2006; Fontaine et al. 2009; Jones and Cresswell 2010). For example, the life cycle of avian species depends on accumulated temperature (i.e., the amount of sunlight available over time). Climate change, i.e., changes in temperature and precipitation has altered the hydrological process of wetlands that ultimately influences avian community

Table 21.1 List of bird species occurs in high-altitude wetlands

Family	Scientific name	Common name	Status	Authors
Accipitridae	*Haliaeetus leucoryphus*	Pallas's fish-eagle	Migrant	Otto (2001); Namgail (2005)
	Pandion haliaetus	Osprey (Fig. 21.8)	Vagrant	Otto (2001); Namgail (2005)
Anatidae	*Anas acuta*	Northern pintail	Migrant	WWF (2012); Khan et al. (2012)
	Anas clypeata	Northern shoveler	Migrant	Otto (2001); Namgail (2005); WWF (2012); Khan et al. (2012)
	Anas crecca	Common teal	Migrant	Otto (2001); Namgail (2005); WWF (2012); Khan et al. (2012)
	Anas penelope	Eurasian wigeon	Migrant	Otto (2001); Namgail (2005)
	Anas plathyrhynchos	Mallard	Migrant	Otto (2001); Namgail (2005); Gogoi et al. (2010); WWF (2012); Khan et al. (2012)
	Anas querquedula	Gargany	Migrant	Otto (2001); Namgail (2005)
	Anas strepera	Gadwall	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Anser anser	Grey-legged goose	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Anser indicus	Bar-headed goose (Fig. 21.9)	Migrant	Otto (2001); Namgail (2005)
	Aythya ferina	Common pochard	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Aythya fuligula	Tufted pochard	Migrant	Otto (2001); Namgail (2005)
	Aythya nyroca	Ferruginous pochard	Migrant	Otto (2001); Namgail (2005)

Table 21.1 (continued)

Family	Scientific name	Common name	Status	Authors
	Mergus merganser	Common merganser/Stream-lined duck	Migrant	Otto (2001); Namgail (2005)
	Rhodonessa rufina	Red-crestedpochard	Migrant	Otto (2001); Namgail (2005)
	Tadorna ferruginea	Brahminy selduck	Migrant	Otto (2001); Namgail (2005)
	Tadorna ferruginea	Ruddy shelduck	Migrant	Mazumdar et al. (2011)
	Ardea cinerea	Grey heron (Figs. 21.9 and 21.10)	Migrant	Otto (2001); Namgail (2005); WWF (2012); Khan et al. (2012)
Ardeidae	*Botaurus stellaris*	Great bittern	Migrant	Otto (2001); Namgail (2005)
	Bubulcus ibis	Cattle Egret (Fig. 21.11)	Migrant	Otto (2001); Namgail (2005)
	Egretta garzetta	Little egret (Fig. 21.12)	Resident	Otto (2001); Namgail (2005)
	Ixobrychus minutus	Little bittern	Migrant	Otto (2001); Namgail (2005)
Charadriidae	*Arenaria interpres*	Ruddy turnstone	Migrant	Otto (2001); Namgail (2005)
	Charadrius alexandrinus	Kentish plover	Migrant	Otto (2001); Namgail (2005)
	Charadrius dubius	Little ringed plover	Migrant	Otto (2001); Namgail (2005)
	Charadrius hiaticula	Common ringed plover	Migrant	Otto (2001); Namgail (2005)
	Charadrius mongolus	Lesser sand plover	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Pluvialis fulva	Pacific golden plover	Migrant	Otto (2001); Namgail (2005)
	Pluvialis squatarola	Grey plover	Migrant	Otto (2001); Namgail (2005)
	Vanellus vanellus	Northern lapwing	Migrant	Otto (2001); Namgail (2005)
Falconidae	*Falco columbarius*	Merlin	Migrant	Otto (2001); Namgail (2005)
	Falco subbuteo	Eurasian hobby	Migrant	Otto (2001); Namgail (2005)
	Falco tinnunculus	Common kestrel	Resident	Khan et al. (2012)

Table 21.1 (continued)

Family	Scientific name	Common name	Status	Authors
Glareolidae	*Glareola pratincola*	Collared pratincole	Migrant	Otto (2001); Namgail (2005)
Gruidae	*Grus leucogeranus*	Siberian crane	Migrant	Otto (2001); Namgail (2005); Khan et al. (2012)
	Grus nigricollis	Black-necked crane	Migrant	Otto (2001); Namgail (2005); Khan et al. (2012)
	Grus virgo	Demoiselle crane (Fig. 21.13)	Migrant	Otto (2001); Namgail (2005); Khan et al. (2012)
Ibidorhynchidae	*Ibidorhyncha struthersii*	Ibisbill	Migrant	Otto (2001); Namgail (2005)
Jacanidae	*Hydrophasianus chirurgus*	Pheasant-tailed jacana	Migrant	Otto (2001); Namgail (2005)
Laridae	*Larus brunnicephalus*	Brown-headed gull	Migrant	Otto (2001); Namgail (2005)
	Larus ichthyaetus	Pallas's gull	Migrant	Otto (2001); Namgail (2005)
	Larus minutus	Little gull	Migrant	Otto (2001); Namgail (2005)
	Larus ridibundus	Black-headed gull	Migrant	Otto (2001); Namgail (2005)
Motacillidae	*Motacilla alba*	White wagtail	Resident	Otto (2001); Namgail (2005); Khan et al. (2012)
	Motacilla cinerea	Grey wagtail	Resident	Otto (2001); Namgail (2005); Khan et al. (2012)
	Motacilla flava	Yellow wagtail	Resident	Otto (2001); Namgail (2005)
	Motacilla maderaspatensis	Large pied wagtail	Migrant	Otto (2001); Namgail (2005)
	Motacilla citreola	Citrine wagtail	Migrant	Khan et al. (2012)
Podicipedidae	*Podiceps cristatus*	Great crested grebe	Migrant	Otto (2001); Namgail (2005)
	Podiceps nigricanus	Black-necked grebe	Migrant	Otto (2001); Namgail (2005)
	Tachybaptus ruficollis	Little grebe	Resident	Otto (2001); Namgail (2005)
Rallidae	*Crex crex*	Corn crake	Migrant	Otto (2001); Namgail (2005)

Table 21.1 (continued)

Family	Scientific name	Common name	Status	Authors
	Fulica atra	Common coot	Resident	Otto (2001); Namgail (2005); WWF (2012); Khan et al. (2012)
	Gallinula chloropus	Common moorhen (Fig. 21.14)	Resident	Otto (2001); Namgail (2005); WWF (2012); Khan et al. (2012)
	Porzana porzana	Spotted crake	Migrant	Otto (2001); Namgail (2005)
	Porzana pusilla	Ballion's crake	Migrant	Otto (2001); Namgail (2005)
	Rallus aquaticus	Water rail	Migrant	Otto (2001); Namgail (2005)
Recurvirostridae	*Himantopus himantopus*	Black-winged stilt (Fig. 21.15)	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Recurvirostra avosetta	Pied avocet	Migrant	Otto (2001); Namgail (2005)
Scolopacidae	*Actitis hypoleucos*	Common sandpiper (Fig. 21.16)	Migrant	Otto (2001); Namgail (2005); Khan et al. (2012)
	Calidris alpina	Dunlin	Migrant	Otto (2001); Namgail (2005)
	Calidris ferruginea	Curlew sandpiper	Migrant	Otto (2001); Namgail (2005)
	Calidris minuta	Little stint (Fig. 21.17)	Migrant	Otto (2001); Namgail (2005); Khan et al. (2012)
	Calidris temminckii	Temminck's stint	Migrant	Otto (2001); Namgail (2005)
	Gallinago gallinago	Common snipe	Migrant	Otto (2001); Namgail (2005)
	Gallinago solitaria	Solitary snipe	Migrant	Otto (2001); Namgail (2005)
	Gallinago stenura	Pintail snipe	Migrant	Otto (2001); Namgail (2005)
	Limosa limosa	Black-tailed godwit	Migrant	Otto (2001); Namgail (2005)
	Numenius arquata	Eurasian curlew	Migrant	Otto (2001); Namgail (2005)
	Numenius phaeopus	Whimbrel	Migrant	Otto (2001); Namgail (2005)

Table 21.1 (continued)

Family	Scientific name	Common name	Status	Authors
	Phalaropus lobatus	Red-necked phalarope	Migrant	Otto (2001); Namgail (2005)
	Philomachus pugnax	Ruff	Migrant	Otto (2001); Namgail (2005)
	Tringa glareola	Wood sandpiper (Fig. 21.18)	Migrant	Otto (2001); Namgail (2005)
	Tringa nebularia	Common greenshank	Migrant	Otto (2001); Namgail (2005)
	Tringa ochropus	Green sandpiper	Migrant	Otto (2001); Namgail (2005)
	Tringa stagnatlis	Marsh sandpiper	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Tringa totanus	Common redshank	Migrant	Otto (2001); Namgail (2005)
	Xenus cinereus	Terek sandpiper	Migrant	Otto (2001); Namgail (2005)
Stercorariidae	*Stercorarius parasiticus*	Parasitic jaeger	Migrant	Otto (2001); Namgail (2005)
Sternidae	*Chlidonias hybridus*	Whiskered tern (Fig. 21.19)	Migrant	Otto (2001); Namgail (2005)
	Chlidonias leucopterus	White-winged black tern	Migrant	Otto (2001); Namgail (2005)
	Gelochelidon nilotica	Gull-billed tern	Migrant	Otto (2001); Namgail (2005)
	Sterna albifrons	Little tern	Migrant	Otto (2001); Namgail (2005)
	Sterna hirundo	Common tern	Migrant	Otto (2001); Namgail (2005); WWF (2012)
	Sterna paradisaea	Arctic tern	Migrant	Otto (2001); Namgail (2005)

Fig. 21.8 Bar-headed geese departing from high-altitude wetland

Fig. 21.9 Occurrence of grey heron in wetland habitat

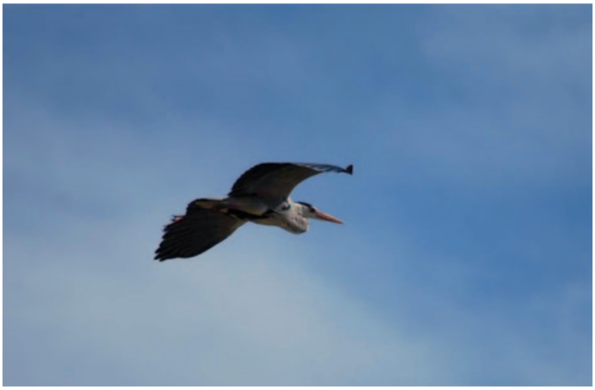

Fig. 21.10 Grey heron flying over wetland area

structure, home range, food resources, and breeding ecology (Root and Huges 2005; Devictor et al. 2008; Furniss et al. 2008; Jayachandran 2013). For example, migrant bird species are vulnerable to changes in temperature and food resources (i.e., during winter they migrate from their native habitat due to severe cold and scarcity of food resources).

Fig. 21.11 Cattle egret loafing along water body edge

Fig. 21.12 Little egret walking in shallow water

Fig. 21.13 Demoiselle crane in captivity

Research across different habitats has highlighted that climate change effects on avian community structure directly and indirectly (Robinson et al. 2009; Both et al.

Fig. 21.14 Common moorhen walking on aquatic plants

Fig. 21.15 Black-winged stilt foraging in shallow water

Fig. 21.16 Common sandpiper foraging on invertebrate

2010; Kings and Finch 2013). Climate change is a major driving factor which negatively affects the phenology, distribution, and abundance of bird species (Huntley et al. 2008; Moller et al. 2008; Gregory et al. 2009) inhabiting high-altitude wetlands. Fluctuation, i.e., the rise and fall in temperatures due to climate change, may

Fig. 21.17 Wood sandpiper searching for food in shallow water

Fig. 21.18 Little stint foraging in shallow water

Fig. 21.19 Whiskered tern loafing on dead wood fallen in wetland

affect movement, reproduction, time of breeding, migration, and survival of avian species (Crick 2004; Gordo 2007; Peterson 2009). Bird species may move to other areas due to fluctuation in temperature that may be insufficient and less suitable for them to fulfill their needs (La Sorte and Jetz 2010). The movement of avian species is closely linked with both winter and summer temperatures (Kings and Finch 2013). It has also been reported that climate change has negatively impacted 75 % of bird species in different habitats (BirdLife International 2009). Species that are likely to experience a substantial proportional range loss and shift (with low overlap between present and projected future range) as a consequence of climate change are of particular concern. In Europe, endemic bird species are threatened by climate change due to substantial proportional range loss and shift in habitat (Huntley et al. 2007; BirdLife International 2008).

Climate change has altered the microclimate variables (such as temperature, relative humidity, and rainfall pattern), which have affected the food resources and wetland habitats through floods and drought that directly and indirectly has effects on avian diversity. The flowering and fruiting pattern in plant communities of high-altitudinal wetland ecosystemsare altered due to climate change (i.e., rise in temperature and unpredictable rainfalls). Temperature and precipitation are major factors, which play significant roles in distribution, growth, productivity, and reproduction of plants and animals. It has been estimated that 20–30 % of plant and animal species will be at the risk of extinction, if the temperature rises by more than 1.5–2.5 °C. Higher temperature may cause thermal expansion and increase the amount of moisture that evaporates from land and water, leading to drought in many areas. As temperatures rise globally, droughts will become more frequent and more severe, with potentially devastating consequences of water supply (Allen et al. 2005). Lands affected by drought are more vulnerable to flooding during rainfall. Hot temperatures and dry conditions may displace wildlife species from one area to another and even cause mortality.

Rapid changes in environmental conditions such as temperature and precipitation may affect habitat selection, shift in movement, and breeding behavior (Visser 2008). This concern has created interest in identifying vulnerability due to climate change on avian diversity (Cormont et al. 2011) as indicated by elevation and latitudinal shifts in their distributions.

Likewise, less snowfall in winter, warmer temperatures in summer and more rainfall in winter may cause change in vegetation structure and species composition, which is the habitat of a wide array of bird species. In addition, melting of glaciers adds more fresh water into the oceans that inundate low-lying areas and islands, threaten dense coastal populations, erode shorelines, damage property, and destroy ecosystems such as mangroves and wetlands that protect the coasts against storms. When sea level rises, it reduces the land areas that instantly affects vegetation that offer air, water, food, and shelter to animals in high-altitude wetland habitats.

Furthermore, changes in rainfall and temperature will affect many animal and plant species around the world. Some species might be unable to adapt quickly to climatic changes, due to this, their population will be adversely affected, and their habitat might not be suitable for survival.

Evidently, it shows that climate change has profoundly detrimental effects on wetland ecosystems and avian diversity. For example, decreased precipitation and snowfall leads to increase in temperature that may cause drought and floods in high altitudes. The flooding may increase water runoff from glaciers due to warming, which may cause erosion along the banks of wetlands and cause a situation (i.e., deposit sediments) that affects habitat suitability of wetlands for avian diversity, i.e., some bird species have moved to other areas due to low suitability of habitat and rate of food capture due to rise of water level. Likewise, droughts also cause shift in vegetation and affects food resources, i.e., food resources become visible and easy to catch by predators and food such as fishes and amphibians may die due to less availability of water resources. This may change the wetland morphology, i.e., cause shift in vegetation, change vegetation structure, and change in composition that ultimately affects wetland productivity and nutrient cycles.

Climate change may cause the following major effects on different ecosystems as reported by (Furness et al. 2013):

1. Low precipitation of snow, smaller snowpacks, and earlier snowmelt.
2. Increased incidence of rain-on-snow flooding.
3. Reduced dry season in stream flows.
4. Increase moisture (relative humidity) which stresses vegetation and also increases stress on aquatic ecosystems.
5. Shift in flora and fauna species.
6. More frequent, larger floods and longer droughts.
7. Reduced water quality through increased erosion.
8. Species extirpation, population pressures, and water scarcity.
9. More extensive and severe insect outbreaks.
10. More frequent and larger incidences of severe wildfires.

21.7 Effects of Climate Change on Avian Food Resources

Amphibians are a food source for a variety of avian species, especially carnivorous waterbirds and terrestrial birds. The occurrence and richness of amphibians depends on availability of water resources. Water is a major factor for breeding and survival of amphibians. Climate change has adversely altered the hydroperiod which refers to the times of water availability (Olson and Saenz 2013a) that ultimately affects distribution and diversity of amphibians, i.e.,restricted movement and not being able to shift their habitat (Corn 2005; McCallum 2010). This indicates that amphibians are at high risk due to low tolerance of temperature and moisture changes (Olson and Saenz 2013a). In addition, climate change may cause mass mortality of eggs, tadpoles, and metamorphosis of amphibians thus resulting in population decline (Blaustein and Olson 1991).

Reptiles are also a major food source for a variety of carnivorous birds. Reptiles have smaller home range (Lawing and Polly 2011) and they are unable to shift their home range. Due to smaller home ranges, they are highly vulnerable to fluctuation in temperature (Araujo et al. 2006; Zani and Rollyson 2011). The reproduction and home range of reptiles, especially lizards, are closely associated with temperature and microhabitat characteristics. Climate change may have altered their microhabitat due to fluctuation in temperature and precipitation, which may cause failure of their reproductive cycles (Olson and Saenz 2013b). Temperature fluctuation in a particular habitat may alter the reproduction cycle and reduce movement of reptiles, i.e., potentially affect sex ratios which may cause low populations due to reproductive failure (Gibbons et al. 2000). It has been reported that around 12 % of lizards have been lost due to climate change, i.e., altered thermal niches (Sinervo et al. 2010).

Conclusion and Future Perspective

The current review highlights that climate change is a major driving factor that affects avian diversity through various ways: altered microclimate factors (temperature, relative humidity, and rainfall pattern) and microhabitat characteristics that have caused a shift in home range, food resources, and breeding ecology of various bird species inhabiting high-altitude wetland habitats. In this review, we focus on the effects of climate change on birds, habitats, and food resources. This review indicates that climate change affects phenology, distribution, migration season (i.e., arrival and departure), and breeding ecology of avian species. Furthermore, we have found that climate change may cause drought and flooding in high-altitude wetland habitats, thus changing the ecology of particular wetland habitats. Likewise, the current information on the effects of climate change on avian diversity, their habitats, and food resources is scarce; thus, there is an urgent need to examine in detail the effects of climate changes on various aspects of avian species and high-altitude wetland ecosystems that will help in their future conservation and management activities of high-altitude wetland habitats and avian species. We expect the findings will provide basic guidelines to manage the wide array of avian species utilizing these fragile wetland habitats.

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Chapter 22
Flora and Plant Formations Distributed in At-Bashy Valleys–Internal Tien Shan in Kyrgyzstan and Interactions with Climate

Nazgul Imanberdieva

22.1 Introduction

Kyrgyzstan is a mountainous country. The relief is the determining factor for the high-altitude zone of natural ecosystems. Nearly 90 % of the total area of the country is located at an altitude of 1500 m above sea level (asl), and one-third part is at an altitude of 3000 m asl. The average altitude is approximately 2750 m. However, more than half of the higher plants (70 % of the families; 90 % of the genera) throughout central Asia grow on a relatively small area (199,900 km^2). At-Bashy valley is located on the south side of the At-Bashy range. The highest peak is yellow Jel-Tegirmen, with an altitude of 4500–5000 m asl. The slopes of At-Bashy range are covered by fir forests, dominated by *Picea schrenkiana*. The forests of *Sorbus tianschanica* and *Salix tianschanica* are distributed at the foot of the spruce forests, and these are mixed with *Ribes meyeri, Berberis oblonga, Rosa alberti, Crataegus altaica,* and others. In the spruce forest, the herbaceous plant cover is composed of *Rhodiola semenova, Rheum reticulatum, Fragaria vesca,* and *Campanula glomerata*. There is a very effective fragrance felt, especially in summer. The junipers grow above the spruce forests, followed by alpine meadows at higher elevations dominated by *Allium odorum*.

The north side of the valley at At-Bashy is surrounded by Kara-Too, Koshoi-Too, Ala-Myshik, and Borkoldoi Mountains. This part is sunny, with low rainfall and scanty vegetation. The total plant diversity in the country is represented by more than 4100 species of higher plants, of which 1600 have a high economic and practical value.

Steppes are one of the dominant types of vegetation, occupying an area of 474,708 km^2 (25.6 % of the territory). The area of steppes of inner Tien Shan is 434,000 ha. The domination of steppe vegetation in the country and in the study area can be affiliated to the aridity in the area and general climatic regime as well as

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Fig. 22.1 The geographical position of At-Bashy valley internal Tien Shan Mountains in Kyrgyzstan. (Scale 1: 500,000. 1 cm=5 km)

degradation of pastures. The steppe vegetation is of great scientific interest and has great economic importance for the livestock raising in the republic.

The increased human impact on natural ecosystems leads to greater disruption of the plant communities: strengthening sinanthropization of vegetation, loss of productivity, and weakening soil conservation characteristics. The vegetation on Tien Shan mountain range is of great importance, because pasture degradation proceeds more intensively than in the plains. The intensive anthropogenic impacts are hindering the natural recovery of native vegetation in these areas.

At-Bashy valley occupies the eastern part of the At-Bashy–Kara-Koyun basin of the inner Tien Shan. It extends from the source river At-Bashy (Fig. 22.1) to the confluence with the river. Kara-Koyun is more than 80 km, depression bordered by high mountain ranges—in the south is At-Bashy, in the north the Naryn-Too. At-Bashy valley is made up of Tien Shan tectonic intermountain trough. According to Sergunkova (1937), Shumskaya (1953), the geological structure of At-Bashy depression involves very ancient, Precambrian and Paleozoic, metamorphic rocks and relatively young, Cenozoic (Tertiary and Quaternary), sedimentary rocks. Precambrian deposits are widespread in the northern macroslope of At-Bashy range.

These can be traced along its entire length, occupying the main part of the ridge in the middle of the strip, with a width of 5–7 km. The Paleozoic sediments are common in almost all contouring cavities of mountain ranges. Tertiary sediments typical of the northern part of the basin form a wide stretch of strip along the southern slope of the ridge of the Naryn-Too. They are composed of yellow-gray and red-colored clays, conglomerates, sandstones, and limestone. Quaternary deposits are presented by the ancient Quaternary conglomerates and proluvial river sediments, being common in the valleys of the rivers and streams, filling the bottom of the trough and making up the floodplain terraces in the form of clastic material, which is an aggregate of sand, loam, and clay. One of the characteristic features of the relief of Kyrgyzstan is the staging device and the availability of high-altitude layering. Near mountain plains, areas with low counters are formed, and low mountains above the

Fig. 22.2 At-Bashy range

piedmont zone lie in the foothills of the mountain range, which then extend to a middle and high relief (Isayev et al. 1962).

Geologically, Tien Shan forms three large units of arc: northern, middle, and southern (Mushketov 1947; Nalivkin 1926; Schulz 1948). At-Bashy ridge belongs to the southern arc. It is located in the north of Lake Chatyr-Kul, between the valleys of the Ak-Say and At-Bashy–Kara-Koyun, whose length is 150 km. The highest area of ridge At-Bashy is located in the middle part (4786 m asl); the altitude of the ridge drops to the west and east to 3500 m around the central ridge area. The individual passes are above the snow line. The slopes are cut short cross with subsequent deep gorges, often with glaciers (Fig. 22.2).

Naryn-Too—a major northwestern spur Borkoldoi is about 85 km long—has a narrow crest on the ridge in places above the snow line. The low mountains are widespread at the foot of the northern ranges of the At-Bashy depression. The vast bed of gravel stratum occupies these depressions on the surface of which meander streams of At-Bashy (Skvaletsky 1959).

In morphological terms, At-Bashy depression shows the following features:

1. Naryn ridge—with fold-block uplifts showing denuded surface in the west.
2. Extensive surface of the upper terraces of the complex river At-Bashy with lateral inflows.
3. Modern alluvial floodplain-channel space, and the lower terraces of the river At-Bashy.
4. Podmyta narrow foothill trail at the foot of the At-Bashy range.
5. Low upland terraces and hanging valleys of the lower slope of the At-Bashy-Too.
6. Antitsedentnye gorge Bosogo and At-Bashy.
7. At-Bashy anticline—a ridge, slightly complicated by faults running along the bottom.

The ranges, limiting At-Bashy trough from the north, are much lower. All the ridges surrounding At-Bashy depression are characterized by extensive development of denuded surfaces. Lower areas of the depression are used for crop cultivation as well as forage grasses (Isayev et al. 1962).

Kyrgyzstan is located in the center of the world's largest continent—Eurasia, nearly 3000 km away from the Arctic, 5000 km from the Antarctic, and 2000 km from the Indian Ocean (Arabian Sea), surrounded by a vast desert, which determines the character of a continental climate. Inner Tien Shan is a mountainous area, a vast closed territory, 2000–3500 m asl, and the natural conditions are similar to the central Asia in general.

The climatic features in internal Tien Shan, Kyrgyzstan, are very diverse due to differing topography. In the east, winter precipitation decreases (Ryazantseva 1965). The climatic factors like temperature and moisture in inner Tien Shan play an important role due to its relief, a relatively low latitudinal position and distance from the ocean as is common throughout central Asia. Since it is surrounded on all sides by mountain ranges with altitudes of 4000 m or more, with alternating ridges and intermountain highland valleys, all these greatly affect local circulation of air masses, the regime of temperature, and humidity. The surrounding area of the mountain ranges retains the windward slopes with penetration from outside the northwestern and northern humid air currents, which create important climatic sections. The climate in the At-Bashy valley is similar to the north of the Naryn basin. They share similar altitudes, uniform climatic conditions, and are dominated by the same plant associations. The average air temperature of At-Bashy valley–inner Tien Shan during the growing season (April–September) is 4.2 –15.7 °C (average of 1990–2005 years).

The highest maximum temperature is recorded in July 1997 (19.9 °C) and August 1994 (19.5 °C); the lowest temperature was observed in January 1994 and 2002 (−18.9 °C), 1999 (−17.5 °C), and 1993 (−17.1 °C). The climate of the inner Tien Shan is very different from other physiographic regions, more sharply continental and dry; high altitude has the features of a cold desert. General characteristics of this climate are hot summers and harsh (for the low latitude) winters, the abundance of solar radiation, dry air, and a small amount of precipitation. The maximum amount of rainfall occurred in June 1999 (95 mm), in April 2003 (94.9 mm), in April 2000 (78.1 mm), and in May 1998 (74.9 mm). Another feature of the climate is a sharp contrast of the hydrothermal regime. Average daily temperatures are positive (Chupahin 1959).

Alpine zone of the inner Tien Shan has some specific climatic conditions. The high intensity of the solar radiation promotes strong heating of the soil, while the temperature remains relatively low. This leads to an unstable equilibrium of the atmosphere, to the constant daily convection, accompanied by the development of clouds and thunderstorms. As a result, the weather is very changeable: bright days are quickly replaced by cloud cover, short spells of torrential rains, or sometimes hail and snow. The average annual air temperature is low. Characteristic of the temperature regime is a sharp difference in temperature between winter and summer, day and night. Through years of research (2001–2005), the highest temperature was measured in July 2001 (18.2 °C) and the lowest in January 2002 (−18.9 °C) Fig. 22.2. The frost-free period (May–September) is an average of 140–150 days. The sum of effective temperatures is in the range of 2.5–50 °C. Spring frosts occur in May while the autumn in the middle of August. Average annual air temperature fluctuations during the period from 2001 to 2005 are in the range of − 2.4 °C–16.7 °C (Fig. 22.3).

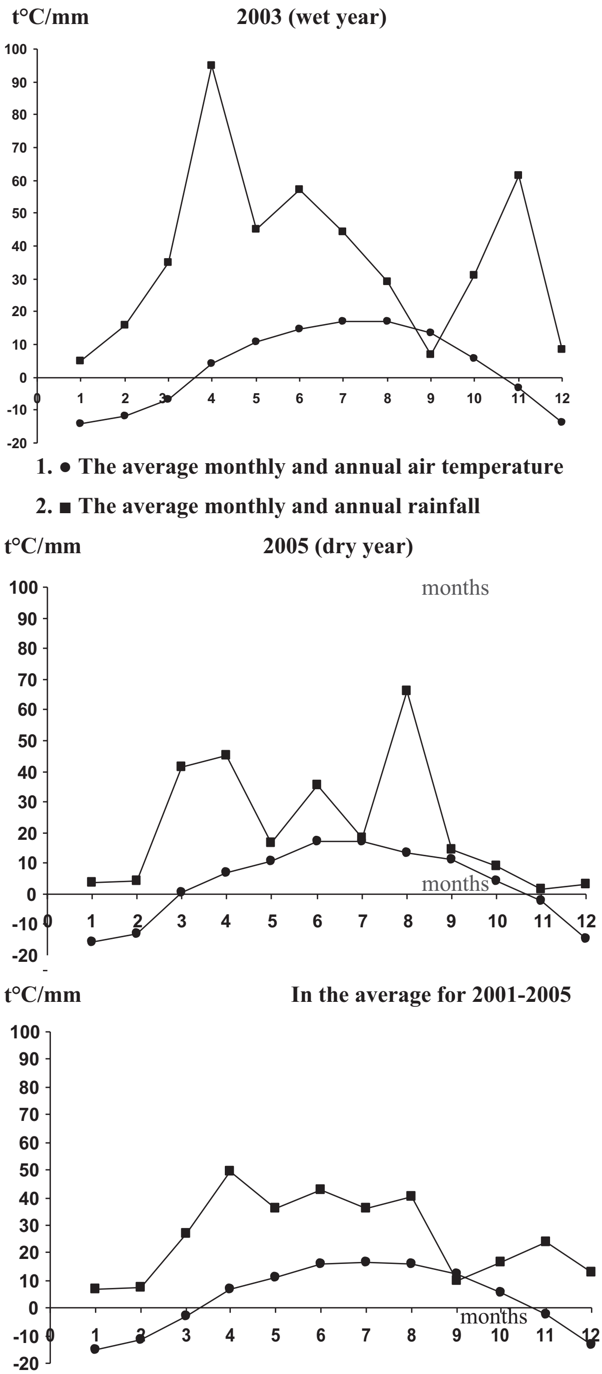

Fig. 22.3 Klimatogrammy: 1. ● The average monthly and annual air temperature. 2. ▪ The average monthly and annual rainfall

Fluctuations in the amount of atmospheric precipitation during the years of study (2001–2005) were mostly dry when annual precipitation was almost the same—257.2 mm (2001) and 258.1 mm (2005). The maximum amount of rainfall was observed in 2003—433.6 mm. Annual rainfall in the second and fourth years of study match—with only a small difference—293 mm in 2002 and 297.3 mm in 2004 (Fig. 22.1). Precipitation is unevenly distributed over the season. Maximum precipitation occurs in the spring and summer, while minimum in the winter. An unusually high amount of rainfall for the years of research was recorded in April 2003 (94.9 mm) and the minimum in May 2005 (16.5 mm; Fig. 22.3).

During 2001–2005, the average rainfall has been 307.8 mm. The snow cover in the At-Bashy valley is visible from mid-November to early April, with an average snow depth nearly 40–50 cm in the lowest part of the depression and precipitation on average is 277 mm/year. The annual, monthly, and daily fluctuations of atmospheric precipitation are quite high. Total precipitation in 1942 was 397 mm in the study area, but 1947 has been recorded as the driest year with a precipitation of 203 mm (Seloustev 1947). Fluctuations in air temperature and rainfall in different years affect the nature of soil processes as well as vegetation of the study area. Intense solar radiation and high wind speeds during the day, combined with low humidity, lead to greater evaporation and, finally, lack of moisture. Therefore, inner Tien Shan, in general, and the study area At-Bashy valley, in particular, are dominated by xerophytic vegetation and gray desert highland soils. Following types of soils and subtypes are distributed in the study area (Mamytov 1963; Openlender 1960).

Brown Desert—Steppe Soils These occupy the lowest and the warm plains of the area and go up the river valley, up to an altitude of 2250 m asl. They are mostly plowed and used for sowing crops. Virgin areas are covered by the communities of *Stipa caucasica, Artemisia fulvella,* and *Achnatherum splendens* steppes.

Brown Soils are Above Light-Brown Soils They are distributed at altitudes of 2250–2750 m, occupying ancient floodplain and river terraces. The loamy soils are met with in At-Bashy piedmont plains, proluvial cones of ridge Baibiche-Too, and the foothills of the Naryn and At-Bashy ranges. Vegetation cover is formed by middle altitude of bunchgrass and forbs of bunchgrass steppe dominated by *Festuca valesiaca*.

Mountain Black Soils They are found on a common narrow strip on the northern macroslope At-Bashy ridge below the spruce forest at altitudes of 2500–2700 m and occupies forest clearings up to an altitude of 2900 m asl. Individual patches are also found in the deep ravines on the southern slopes of the eastern part of the ridge Naryn-Too. The humus content of these soils in the mountains is 10.6–14.0 %; in the upper layer (horizon 2), it is reduced by about half, and then begins to decrease with depth gradually. Vegetation is composed of tall grasslands dominated by *Dactylis glomerata.*

Mountain forest dark-colored soils are common in the northern half of the macro-east ridge in At-Bashy, and small patches are found on the shaded gorges of the southern macroslope of Naryn-Too mountain range at an altitude of 2700–3100 m asl. Relief of the midland is usually heavily dissected. The humus content of the soil varies between 7 and 21, but is drastically reduced with depth. Forest vegetation is *Picea schrenkiana.*

Mountain Meadow Steppe Subalpine Soils They are common in the upper part of At-Bashy valley above the gorge, on the southern macroslope Naryn-Too mountain range at an altitude of 2800 (2900)–3200 (3300) m asl. The humus content is about 9% in the upper layers with a gradual decrease with depth. Vegetation is cryophyte bunchgrass steppe dominated by *Helictotrichon desertorum.*

Mountain Subalpine Meadow Black Soils They are common in the eastern half of the northern macroslope of At-Bashy mountain range, and separate spots are found on shaded exposed southern macroslope of Naryn-Too mountain range. They are located above the spruce forests at an altitude of 3000–3300 m asl. The humus content in the upper layers is high around 16–19% but decreases with depth. Vegetation is cryophyte subalpine meadows of *Phlomoides oreophila.*

Mountain Meadow Alpine Soils They are distributed on the northern ridge of macroslope of At-Bashy (2800–3300 m), on the southern macroslope Baibiche-Too mountain range and a broken belt in the southern macroslope of Naryn-Too mountain range (3400–3700 m). The humus content in the topsoil is about 12%, which markedly decreases with depth. Cryophytic vegetation consists of short grass (alpine)—*Kobresia capilliformis* meadows.

Alluvial Meadow Forest Soils of Riparian Forests and Shrubs They are common in the floodplains of At-Bashy on shallow river sediments. Forest formation consists of *Populus afghanica, Salix argyraceae,* and *Hippophae rhamnoides.*

Flora At-Bashi valley based on our research has 222 species of higher plants belonging to 130 genera and 35 families (Flora of the Flora SSR 1950–1970; Identification Guide to the Plants of Central Asia 1968–1993; Cherepanov 1995). Nine major families of flora include 166 species (75.5 % of the total amount). Nepotism range of flora At-Bashi valley is shown in Table 22.1. The number and percentage of dominant genera is presented in Table 22.2. Asteraceae is the largest family of dicotyledonous plants, with a wide range distributed up to the top, near the alpine snow zone.

22.2 The Main Types of Vegetation in At-Bashy Valley

The vegetation cover in the study area belongs to At-Bashy–Kara-Koyun area, the Naryn District, inner Tien Shan Province, and Asian desert area (Atlas of the Kirghiz Republic 1987).

Subnival Belt Vegetation It includes sparse groups or single cryopetrophyte plants, found in all ranges of the Tien Shan Mountains at altitudes between 3300 and 4000 m. In the At-Bashy valley, it is well represented on the northern slope of the At-Bashy range, scattered among the talus, moraines, outcrops of rocks, cliffs, and rocky slopes. Typical representatives are *Ajania scharnhorstii, Chorispora*

Table 22.1 Number and percentage of species and genera in the dominant families in the study area

The family	Species		Genus	
	Amount	% of total	Amount	% of total
Asteraceae	48	21.6	17	10.3
Poaceae	35	15.9	17	10.3
Fabaceae	18	8.1	7	4.2
Brassicaceae	16	7.2	11	6.6
Lamiaceae	14	6.3	10	6.0
Rosaceae	12	5.4	6	3.6
Chenopodiaceae	9	4.1	8	4.8
Boraginaceae	7	3.1	5	3.0
Ranunculaceae	7	3.1	7	4.2
Total	166	74.8	88	53.0
Oher families	56	25.2	78	47.0
General total	222	100	166	100

Table 22.2 The number of species in the dominant genera of At-Bashy valley

Genus	The number of species	% of total species
Artemisia	17	13.3
Festuca	5	3.9
Oxytropis	7	5.5
Poa	4	3.1
Potentilla	5	3.9
Saussurea	5	3.9
Stipa	4	3.1
Only	47	36.7
Rest of the genus	81	63.3
In total	128	100

macropoda, Draba fladnizensis, Lagotis decumbens, Paraquilegia caespitosa, Potentilla biflora, Pyrethrum pyrethroides, Saussurea gnaphalodes, and *Saxifraga oppositifolia*.

Cryophyte Low Grass (alpine) Meadows These constitute a polydominant community of psihromezofity polycarpic grasses. The characteristic features of the community are the dominance of grasses and forbs; there are no trees and shrubs. Constant species of these cold area plants are thermophilic species distributed on low and high physiologically dry landscapes, which are of importance in the mountains of temperate and subtropical latitudes: the Alps, the Caucasus, the Altai, Tien Shan, the mountain areas of eastern parts of central Asia, and the Himalayas. In high-altitude zone, cryophyte low grass (alpine) meadows occupy a position between cryophytic medium high plants (subalpine) meadows and sparse vegetation of nival zone. The absolute altitude of their distribution in different ranges of botanical and geographical areas in the northern Tien Shan varies between 2800 and 3000 (3600) m, but between 3000 and 3200 (3800) m in the inner Tien Shan, owing to the greater dryness of the climate. The most widespread formation is cobresia and grass-forb meadows, serving as good summer pastures (*jailoo*) for sheep and horses.

22.2.1 Formation of Kobresia capilliformis

There is no consensus on the typological definitions of cobresia meadows in the scientific literature. It was the famous botanist Krasnov who was the first scientist who described *kobresia* Tien Shan. He called them "cobresia wilderness." Later, Vyhodsev, Shennikov, and other scientists reported these as "cobresia wastelands." Ovchinnikov named these as "Turf Pustoshny meadow," and Korovin, Golovkova, Rubtsov as "cobresia meadow" (Ionov 2001). Cobresia grasslands are very characteristic and widely distributed in the ranges of central and inner Tien Shan (At-Bashy, Kokshaal-Too, Sarydzhaz, Kaindy, Inilchek, and other areas), especially in its northeastern part, where the altitudes vary between 2900 and 4000 m, gradually decreasing towards the west and east Kobrezievniki. Their main characteristics are plateau-like tops (syrty), hilly ancient moraine deposits on broad valleys, and the upper reaches of the mountain rivers. In Kyrgyzstan, Kobresia meadows occupy an area of 663,000 ha, and in the inner Tien Shan, 341,600 ha. Floristic diversity is dominated by 20 species of higher plants, with coverage of 100 %. The aboveground mass harvested is 6 t/ha (Research report on certification of pastures 1960). In At-Bashy valley, the *Kobresia capilliformis* formation occupies very small area on the flattops of the northern slope of At-Bashy and southern slopes of the Naryn ridges of rocks and scree, at altitudes of 3200–3700 m asl.

Dominant species is *Kobresia capilliformis*, a perennial, 15–20 cm tall, with a dense turf of the many dark brown leathery shiny parts. Permanent grassland species of Kobresia are *Carex stenocarpa, Leontopodium fedtschenkoanum, Primula algida, Oxytropis globiflora, Ptilagrostis mongholica, Ligularia alpigena, Festuca rubra* and *F. alatavica, Saussurea leucophylla,* and *Kobresia humillis*.

Kobresia meadows are good for summer grazing of sheep and horses. Formation is represented by grass, sedge, and cobresia (*Kobresia capilliformis, Carex stenocarpa, Leontopodium fedtschenkoanum, Primula algida, Oxytropis globiflora, Ptilagrostis mongholica*) combined with *Ligularia alpigena, Festuca rubra,* and *F. alatavic*.

Cryophyte Medium-High Grassy (subalpine) Meadows This community is microthermic with meso- and xeromesophytic grassy polycarpic plants combined with creeping forms of thickets of shrubs and trees like *Juniperus turkestanica, J. sibirica,* and *Caragana jubata*. The lower altitudes are dominated by medium-high grasses of cryophytic meadows, but in the upper limit of distribution, we find *Picea schrenkiana;* the short grass is represented by cryophytic (alpine) meadows. Cryophyte medium-high grass meadows are common in the mountains of temperate and subtropical zones: the Alps, the Carpathians, the Caucasus, the Tien Shan, and the Himalayas. In central Asia, they occupy a wide range from Junggar Ala-Too

Fig. 22.4 *Phlomoides oreophila, Poa pratensis and P. angustifolia, Helictotrichon sehellianum, Alchemilla retropilosa, Geranium regelii,* and *Trollius altaicus* group of associations

(in the east) to the Trans-Alay Range (on the west). Cryophyte medium-high grass meadows are represented in the ranges of central Asia, with two botanical-geographical types: Alai Jungar Tien Shan and Tien Shan. *Jungar tianshanica* cryophyte medium-high grass meadows include *Phlomoides, Alchemilla,* and *Geranium* communities.

In Kyrgyzstan, Tien Shan Jungar cryophyte medium-high grass *phlomoides* meadows cover an area of 336,600 ha, and 121,100 ha in the inner Tien Shan. Total species richness is 70–80 species of higher plants, with 80–90 %. The average height of the grasses is 40–50 cm above ground, and biomass productivity is 6.6 t/ha (Scientific report on the certification of pastures 1960). Cryophyte medium-high grass meadows are low grasses and good summer pastures (*jailoo*).

In At-Bashy valley, meadows are cryophyte medium-high grass formation, including *Phlomoides oreophila,* located above the spruce forest on the northern ridge of macroslope At-Bashy, between the altitudes of 3000–3300 m. Codominants are *Kobresia capilliformis* and *K. humilis, Poa pratensis* and *P. angustifolia, Carex stenocarpa,* and *Ranunculus alberti.* The constant species are *Alchemilla retropilosa, Ligularia alpigena, Leontopodium fedtschenkoanum, Erigeron aurantiacus, Papaver croceum, Trollius altaicus, Geranium regelii* (*Aquilegia atrovinosa*)*, Allium atrosanguineum* (*Bistorta elliptica*) and *Helictotrichon schellianum* (*Festuca kryloviana*). There are associations in this formation, including *Phlomoides oreophila, Kobresia capilliformis* and *K. humilis, Festuca kryloviana, Ligularia alpigena, Leontopodium fedtschenkoanum, Erigeron aurantiacus, Papaver croceum, Trollius altaicus, Phlomoides oreophila, Poa ptatensis* and *P. angustifolia, Helictotrichon sehellianum, Alchemilla retropilosa, Geranium regelii,* and *Trollius altaicus* (Figs. 22.4 and 22.5).

22.2.2 Cryophyte Steppes

According to Lavrenko (1954), steppe vegetation communities include herbaceous perennial micro-mesothermic, xerophytic, semi-xerophytic, and cryoxerophytic turf grasses. Continental climate, topography, and complex history of vegetation favor

Fig. 22.5 *Phlomoides oreophila, Carex stenocarpa, Ranunculus alberti, Aquilegia atrovinosa, Poa angustifolia* and *Juniperus turkestanica* group of associations

the development of mountain steppes in central Asia. Steppes occupy 25.6% of territory of the republic, and are the dominant type of vegetation in the Tien Shan and Alai. Therefore, Kyrgyzstan is known as the mountain-steppe country. At-Bashy valley is characterized by high-altitude cryophyte of bunchgrass with semishrubs in the lower and middle zones of the mountains, together with desert of bunchgrass and forb of bunchgrass prairie vegetation subtypes ("Vegetation Kazakhstan and Central Asia " 1995).

22.2.2.1 Cryophyte of Bunchgrass Steppe

Formation of Helictotrichon desertorum It is distributed in At-Bashy, Naryn, Jumgal, Suusamyr, Son-Kul, Kyrgyz, Talas, Chatkal, Fergana, Alai, and in the valleys—Kara-Kudzhur, Arpa, Aksai, in the hollow of the Lake Issyk-Kul, and the large and small Kemin. *Helictotrichon* is also common in the steppes of western Siberia and the European part of Russia. In the inner Tien Shan area, *Helictotrichon desertorum* steppes extend on 9.0 ha, with a cover of 60%. Average height of the grass is 15–25 cm, with aboveground biomass productivity being 5.3 t/ha (Scientific report on the certification of pastures 1960). In At-Bashy valley formation, *Helictotrichon desertorum* occupies very small area on the northern macroslope of At-Bashy range between nival belt and cryophytic medium-high grass meadows of *Phlomoidesis.*

The dominant species *Helictotrichon desertorum* is a firm bunchgrass, herbaceous member of *Poaceae* with numerous stems up to 60 cm tall. Tufts at the base are shrouded in old leaves. The leaves are rolled into a tube. Flowers are on variegated brownish spikes, and plants grow separately at distances from each other in colonies. Between the tufts, we find *Festuca valesiaca* and *F. Kryloviana, Stipa kirghisorum, Carex stenocarpa, Leontopodium fedtschenkoanum*, *Scabiosa songarica,* and species *Potentilla* and *Oxytropis*. Formation is represented by *Helictotrichon desertorum, Festuca valesiaca,* and *Stipa kirghisorum* group associations.

Fig. 22.6. Coniferous forest in the gorge of the Char in At-Bashy valley. *Picea schrenkiana, Juniperus turkestanica, Caragana jubata,* and *Salix alatavica* group of associations

22.3 The Vegetation of Low Mountains

22.3.1 Coniferous Forests

The forests of *Picea schrenkiana* are found on the eastern part of the northern macroslope of At-Bashy. The undergrowth includes *Sorbus tianschanica*. The main group of associations is *Picea schrenkiana, Juniperus turkestanica, Caragana jubata,* and *Salix alatavica* (Fig. 22.6).

22.3.2 Tall Meadows

22.3.2.1 Formation of Dactylis glomerata

Tall grasslands in Tien Shan mountains are dominated by *Dactylis glomerata,* a main characteristic of the meadow-type vegetation. Dominant species is *Dactylis glomerata,* a mesophytic perennial (Shennikov 1941; Rabotnov 1950).

Dactylis glomerata formation is widespread in the forest meadow zone of Kyrgyzstan. Area of tall grasslands dominated by *Dactylis glomerata* in Kyrgyzstan is 248,000 ha, while in the inner Tien Shan is 149,000 ha. *Dactylis glomerata* has important value in the landscape ranges of Dzhungarian, At-Bashy, and Toguz-Toro in the north and close to the exposed slopes at elevations from 1700 to 3000 m asl. Total species richness of higher plants is 50, with a cover of 80–100%. Average height of the grass is 80–90 cm and aboveground productivity is 13.5 centner/ha. They form tall meadow summer pastures for cattle and horses and are used as hayfields (Vyhodsev 1956; Golovkova 1990, Scientific report on the certification of pastures 1960).

Fig. 22.7 Tall grasslands. *Dactylis glomerata, Legularia* heterohylla, and Trollius altaicus group of associations

In At-Bashy valley, orchard grass formation is spreading on the northern macroslope of At-Bashy range, covering the bottom of spruce forests after clearance in the lower parts of the forest, and found as spots in the deep valleys of the eastern part of the southern macroslope on Naryn range. The herbaceous stems are consumed badly, and poisonous plants found are *Ligularia heterophylla, Anthriscus sylvestris,* and *Aconitum leucostomum.* In At-Bashy valley formation, *Dactylis glomerata* includes *Ligularia heterophylla, Aconitum leucostomum, Anthriscus sylvestris,* and *Trollius altaicus* group of associations (Fig. 22.7).

22.4 Mid-Bunchgrass and Forb Bunchgrass Steppe

22.4.1 Formation of Poa litvinoviana

Poa litvinoviana, Stachys betoniciflora, Origanum vulgare, Galium verum, and *Phlomoides pratensis* with shrubs like *Spiraea hypericifolia* and *Lonicera microphylla* form a group of associations. Desert steppe in At-Bashy valley occupies the lowest part of the basin, and the formations are *Stipa caucasica* and *Artemisia fulvella*.

22.4.2 Formation of Stipa caucasica

Steppes of *Stipa caucasica* show typical ranges in the At-Bashy, Naryn, Jumgal, Son-Kul, and Suusamyr. Outside the grass steppes, these are distributed in the Caucasus, Iran, Mongolia, and Kashgar (Golovkova 1990). Steppes of *Stipa caucasica* in Kyrgyzstan occupy 263,400 ha, while in the inner Tien Shan, it is 144,700 ha, with a herbaceous cover of 50–85 %. The yield of green mass is 4.1 centner/ha. The economic importance of the steppes is that they serve as spring and autumn pastures.

Stipa caucasica is a dense turf and drought-resistant, frost-hardy, and salt-tolerant grass. Colonies are small feathery and dense with constant species like *Stipa oriental* and *S. capillata, Kochia prostrata, Krascheninnikovia ceratoides, Artemisia nigricans,* and *A. elongata*. The vegetation is very sparse in the *Stipa caucasica* steppes desert.

In At-Bashy valley, it is a sagebrush feather group of associations with *Stipa caucasica* and *S. orientalis* and *Artemisia elongata,* involving *Kochia prostrata, Krascheninnikovia ceratoides, Stipa capillata* and *S. caucasica,* and *Artemisia nigricans*.

22.4.3 Formation of Artemisia fulvella

Formation in At-Bashy valley is a group of associations, including *Artemisia fulvella, Stipa capillata* and *S. kirghisorum, Festuta valesiaca,* and *Poa relaxa* with shrubs like *Caragana pleiophylla, Spiraea hypericifolia,* and *Rosa beggeriana*.

22.4.4 Formation of Festuca valesiaca

Mid of bunchgrass and forb of bunchgrass steppe is dominated by *Festuca valesiaca,* with a wide environmental profile in the republic, from the foothills to alpine mountain belt. They occupy river terraces, intermountain valleys, and slopes of the ridges at altitudes between 1400 and 3200 m. Area dominated by fescue steppes in Kyrgyzstan is 535,700 ha, and in the inner Tien Shan, it is 167,700 ha (Scientific report on the certification of pastures 1960).

The characteristic features of the vegetation turf steppes of Kyrgyzstan are the absence of woody vegetation, poor floristic composition, the sparseness of stunting grass, poorly articulated vertical structure, and lack of colorful species. It has particular aspects of herbs specific to the lowland vegetation of the steppes of Russia. Dominant steppes of *Festuca valesiaca* show considerable ecological amplitude, covering the soil and rocky substrates, as an edificator. *Festuca valesiaca* is one of the main cenosis-forming steppes in the republic, prevailing in the edificator of bunchgrass synusia, in indigenous and derivative communities. Grass is resistant to grazing and, under heavy pressure, replaces herbage grasses, forming communities of the steppes, representing one of the initial stages of human degradation.

Festuca valesiaca is a summer and wintergreen plant with long dormancy period. The time of flowering is early summer. It is widely distributed with wide ecological amplitude. *Festuca valesiaca* has high flexibility and adaptability to different environmental conditions and contributes to the formation of a wide variety of communities with varying degrees of participation. The dominant grasses are accompanied by firm bunchgrass forming larger tufts—*Stipa capillata* and *S. kirghisorum,*

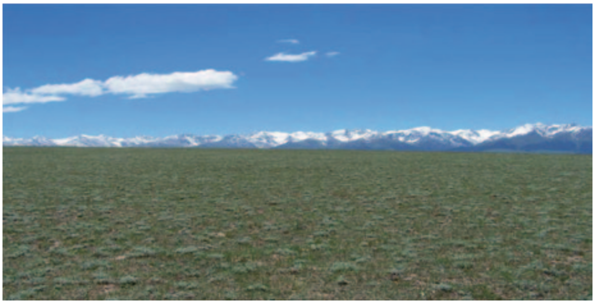

Fig. 22.8 The steppe with *Festuca valesiaca*

Koeleria cristata, Phleum phleoides, Carex turkestanica, Artemisia tianschanica, Hypericum perforatum, Potentilla orientalis, and *Ajania fastigiata*—with shrubs like *Spiraea hypericifolia* and *Cerasus tianschanica*. The cover is 50–70 %, and the green mass yield is 5–6 kg/ha. Barrens are used as spring, autumn, and winter pastures. Flat areas are used for cultivation. It includes a group of associations: *Festuca valesiaca, Stipa capillata, Agropyron pectinatum, Koeleria cristata, Catex turkestanica, Artemisia polysticha* and *A. tianschanica, Hypericum perforatum, Potentilla orientalis, Ajania fastigiata* and *Festuca valesiaca, Artemisia tianschanica* and *A. dracunculus, Hypericum perforatum, Stipa kirghisorum* and *S. capillata, Carex turkestanica, Phleum phleoides,* and *Agropyron pectinatum* (Fig. 22.8).

In the belt of sagebrush grass steppe, low bunchgrass is found at 2600–2700 m altitude. The fragments of cryophytic (subalpine) possess an average height of the grassy meadows. They take in-depth (more wet) form morpho-sculpture, dissecting the soft slope from the top to the foot, in the longitudinal, rather than narrow, vertical stripes (Fig. 22.9).

Flora is not rich in this grassland vegetation; cover is up to 60 % with 40–50 cm tall. Dominant vegetation is *Phlomoides pratensis.* It dominates following uncontrolled grazing (pastoral degradation). The dominant grasses are accompanied by *Koeleria cristata, Helictotrichon desertorum,* and *Elytrigia batalinii,* with artemisia species and forbs: *Artemisia juncea* and *A. rutifolia, Koelpinia linearis, Tragopogon elongatus, Kochia prostrata, Geranium collinum, Potentilla evestita,* and *P. multifida.* Economic value of cryophytic meadows in the small spots of steppe vegetation is insignificant. *Phlomoides* grasslands show productivity up to 16 t/ha.

Achnatherum splendens Steppes In At-Bashy valley, *Achnatherum splendens* formation includes *Achnatherum splendens, Festuca valesiaca, Stipa capillata, Agropyron pectinatum, Koeleria cristata, Artemisia schrenkiana,* and *Salvia nemorosa* group of associations (Fig. 22.10).

22.4.5 Bottomland Forest

On the terrace of the river floodplain of At-Bashy, slightly below the village of Ak-Moyun and the village of At-Bashy, floodplain forests are common on thin forest

Fig. 22.9 Community of *Phlomoides pratensis*—a tract of Sary-Goo At-Bashy valley

Fig. 22.10 *Achnatherum splendens* steppes

sediments with *Populus afghanica, Salix argyracea,* and *Hippophaë rhamnoides*. *Populus afghanica* and *P. talassica, Salix argyracea, Hippophaë rhamnoides, Myricaria squamosa,* and *Clematis orientalis* form group associations (Fig. 22.11).

Much wok has been done in recent years throughout the At-Bashy valley of inner Tien Shan, Kyrgyzstan. Studies concentrated on the northern macroslope of At-Bashy range in inner Tien Shan, where *Caragana* is widespread. The ridge is characterized by abs, altitude being 2500–2800 m. There are attractive dense fir forests, subalpine, alpine, cryophyte, and tall grasslands. Thickets of *Caragana* are

Fig. 22.11 Floodplain forests of At-Bashy valley

Fig. 22.12 Formation of *Caragana jubata* on the pass Kynda At-Bashy valley

stained, clump, and often form solid areas; dominant formation is *Caragana jubata* (Fig. 22.12).

Formation of *Caragana jubata* is widespread over the slopes of the forest meadow belt, in the subalpine section (the valley of the river At-Bashy valley near Bosogo). Thickets of *Caragana* create a unique landscape. In the belt of spruce forest, thickets are as undergrowth, up to 150 cm. These are very original interesting bushes with scimitar-shaped branches.

Thickets develop exclusively on the northern slopes of the mountains, on the abs, at an altitude of 2800 m, where a typical, well-defined group of associations is found: *Caragana jubata–Phlomoides oreophila*. The floristic composition includes 31 species of higher plants, mainly dominated by representatives of the subalpine meadows and rare components of steppe. The grass cover is thin. The ground vegetational cover is 50 %. Other species, though sparse, are *Stipa kirghisorum, Festuca valesiaca,* and *Calamagrostis anthovanthoides*, but their participation is negligible. Group of associations includes *Caragana jubata–Geranium rectum–G. Saxatile* and is represented on very small plots. The smallest numbers of families in the spectra are Fabaceae, Poaceae, Ranunculaceae, and Rosaceae, and species diversity is three to four. Perennial herbs are dominant in the plant cover, 23 (74 %); shrubs, 5 (16 %); 1 dicot; and 1 semishrub and tree. The vegetation includes two endemics: *Alchemilla retropilosa* and *Hedysararum kirghisorum*.

Caragana pleiophylla formation is well expressed in the ranges on Baydully, Naryn, and At-Bashy, and their spurs on the abs, between 1500 and 2000 m. The

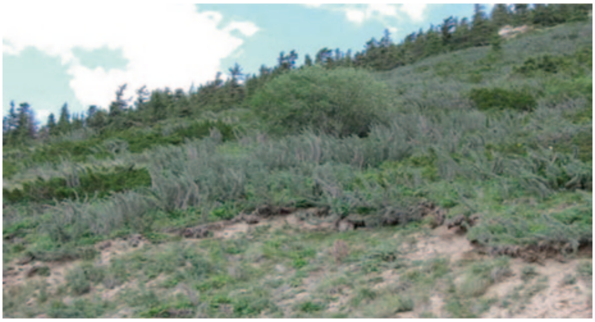

Fig. 22.13 Formation of *Caragana pleiophylla* Ozgorush near the village of At-Bashy valley

bush creates a landscape of steppe and grassland communities between the ridges at At-Bashy and Baydully.

Caragana pleiophylla is scratchy, low, up to 1 m-tall shrub with cushion-shaped yellow flowers. Unlike *Caragana jubata, Caragana pleiophylla* is xerophilous. Species diversity is in the same range. However, structure of vegetation above coenotic value is undersized; other xerophilous taxa are *Festuca valesiaca* and *Stipa capillata,* and the dwarf semishrubs *Artemisia tianschanica* are major components of the group of associations in the formation of *Caragana pleiophylla* (Fig. 22.13).

Species diversity in the *Caragana* of inner Tien Shan and half of the *Caragana* in the northern Tien Shan is poorer, as described by Isakov (1959). There is a significant reduction relative to the composition of their flora recorded by Sovetkina (1930). Dumetosous tangle of *Caragana* is facing population loss due to its excessive use as fuel. In the fodder, they are not valued as a summer pasture. Collection do not exceed 2–4 kg/ha.

The valley of Kara-Koyun is situated on the west part of At-Bashy valley, and Arpa lies in the east. It stretches from northeast to southwest for 180 km and is surrounded by high mountain ranges: from the north by the Naryn-Too, Ala-Mishik, and Kara-Too; from the northwest by Baibiche-Too; and from the south by At-Bashy. According to Shihotov (1970), the absolute altitude of the bottom of the cavity in the middle is 2000 m, 2700 m in the east, and 3000 m in the west. The average of the surrounding cavity ridges is 3700–4200 m.

Kara-Koyun Gorge ("The Black Valley") includes high cliffs, protecting it from deep snowdrifts during the long winter; therefore, there is not much snow. Winter lasts from October to mid-April with frosts up to −40 °C to −50 °C. Even in the summer, we experience frosty nights and daytime temperatures are rarely above 20 °C. The gorge is located in such a way that at any time of the daylight, one of its slopes is always under sunlight. The valley has long been known for its valuable fodder plants. Currently, local people prefer to buy grass for hay mainly from this valley, because the cattle eat the hay without wasting and rapidly gain weight. In winter, these grasses emit a pleasant aroma. In 1930, before the war, people in the valley of Kara-Koyun cultivated barley and were getting a rich harvest. Kara-Koyun stretches from Kazybek village (Border Guard) to passage Ak-Beyit valley, spread over an area of 20–25 km in length and 10–15 km in width (Fig. 22.14).

Fig. 22.14 At-Bashy–Kara-Koyun valley

Sagebrush cereal steppe grasslands occur in almost all physiographic regions of inner Tien Shan, but the most characteristic lands are found in At-Bashy–Kara-Koyun cavity. Their area in the inner Tien Shan is around 430,000–440,000 ha. Within the inner Tien Shan, there are also widespread feather grass and sagebrush steppes, with a total area of about 170,000 ha (Scientific report on the certification of pastures 1960). They have the highest grazing significance. These pastures are formed under dry extreme continental climate with little rainfall, and are characterized by constant winds, which dry the soil. Sagebrush cereal steppes are most common in the lower belt of mountain steppes, and occupy the flat areas of the foothills, mainly southeast and southwest exposures at altitudes between 2200 and 2700 m. The soils are brown, light brown, loamy, and nonsaline; humus content is 5–6 % (Openlender 1961).

The vegetation is of medium thickness, and in wet years, there is a thick cover (50–70 %), and sod of the soil surface is 50 %. The average height of the grass in the period of maximum development ranges from 20 to 25 cm, even 30 to 35 cm. The species composition is not rich, and there are about 50 species of plants: *Festuca valesiaca, Stipa capillata, S. caucasica*, *Agropyron cristatum, A. pectinatum*, *Bromus oxydon,* and others. Among the herbs fescue, *Festuca valesiaca* is dominating. In the herbaceous cover, there are *Artemisia tianschanica* and *Carex turkestanica*; from legumes, we find *Astragalus tibetanus, A. fetissowii, Oxytropis atbaschi*; *Trigonella orthoceras, Medicago falcate,* and others. Other associates are *Eremopyrum bonaepartis, Phleum phleoides, kraschenіnnikovia ceratoides, dracocephalum integrifolium,* etc. In the herbaceous cover, we also come across poisonous plants: *Alyssum desertorum, sedum ewersii, Ceratocephala testiculata, Astragalus platyphyllus,* and weeds like *Lappula microcarpa*. Growing season begins in late April–early May and ends in late August–early September.

Productivity of pastures of At-Bashy–Kara-Koyun cavity during the period of maximum development reaches about 15 hwt/ha. In autumn, there is a decrease in the harvest due to the drying plants. The greatest decrease is observed in October. In the west of the valley is At-Bashy and in the east of the valley is Arpa valley of Kara-Koyun (Fig. 22.15).

The valley of Kara-Koyun near the border of Kyrgyzstan and China, at an altitude of 3300–3500 m asl, is known as the historical and cultural area on Silk Road, where most ancient monuments of central Asian architecture—Tash Rabat—have been built around thirteenth to fifteenth centuries. Tash Rabat was a coaching inn for merchants and travelers on the ancient Silk Road traveling from central Asia to China (Fig. 22.16).

Fig. 22.15 Gorge Kara-Koyun

Fig. 22.16 Stone structure of Tash Rabat

Fig. 22.17 Formation of *Artemisia tianschanica*, *Ziziphora tomentosa*, *Pulsatilla campanella*, *Stipa capillata*, and *Festuca valesiaca*

The tract of Tash Rabat is perfect place for grazing. Year-round, all kinds of livestock, including yaks, are seen here. The characteristic features of the vegetation cover are bunchgrass and forb of bunchgrass steppe. The tracts at Tash Rabat At-Bashy valley are treeless, with low species richness, lacking colorful herbs, typical of lowland steppes of Russia, identical to the steppes of the Tien Shan and Altai, Kyrgyzstan. In the tract of Tash Rabat, fairly well-represented forbs are bunchgrass–herb wormwood formation (*Artemisia tianschanica, Ziziphora tomentosa, Pulsatilla campanella, Stipa capillata, Festuca valesiaca*) alpine steppe (Figs. 22.17 and 22.18).

Leontopodium fedtschenkoana Leontopodium in the grass cover steppe is very attractive and decorative, but due to the exceptional beauty, it has been destroyed. Rare decorative plants are in need of protection.

Fig. 22.18 *Leontopodium fedtschenkoana*

Conclusions

At-Bashy valley of the inner Tien Shan, Kyrgyzstan, is a highland region, and the average altitude is 2000–3500 m asl. The characteristic features of the climate are little atmospheric moisture (269–277 mm/year), with a maximum rainfall in the second half of the summer; evaporation rate is much higher than the amount of precipitation. Average annual temperature is +2.7 °C. There are substantial differences in air temperatures in summer and winter, even during the day and night. The area is dominated by xerophytic vegetation and gray desert highland desert soils, with light brown saline soils under the steppes. Reports clearly signify that the glaciers in the country are melting and water will become a much bigger problem in future. All these developments need an urgent and constructive action. There are 222 species of higher plants belonging to 130 genera and 35 families. Economically, the vegetation of the study area is perfect fodder for all kinds of farm animals: sheep, horses, and cattle. The plant diversity will get its share from these interferences. The vegetation is of poorly represented synusia, ephemerals, due to hydrothermal regime, cold and dry spring. A distinctive feature of the spectrum of life-forms is dominance of semishrubs (species of the genus *Artemisia*). This is because of a long and intensive animal grazing. Conservation and restoration of alpine flora of the inner Tien Shan is important under the UN environmental conventions of global importance on Biological Diversity and the Convention to Combat Desertification.

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Chapter 23
Ecological Conditions and Vegetation of Subalpine Zone of Kaz Mountain (Mount Ida, NW Turkey)

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23.1 Introduction

Mountain systems account for roughly 21% of the terrestrial surface area of the globe and are found in all continents. These ecosystems are highly sensitive to climate change. Recent scientific studies led by the experts, scientists, and the Intergovernmental Panel on Climate Change (IPCC) has revealed that global climate change is happening and will present practical challenges to local mountainous ecosystems.

Analysis and estimates have shown that the magnitude of the climate change rises along with elevation. This condition is observed as changes in temperature and in precipitation patterns. There is a critical relationship between the climate change, biodiversity, and human activities. The ability of species to adapt to new conditions at high altitudes is limited and these species will have to migrate. Therefore, mountainous regions resemble islands surrounded by other ecosystems (Busby 1988). The past climate changes have demonstrated that most of the plant species change genetically rather than adapting to the new changes (Huntley 1991).

Mountains are an important source of water, energy, minerals, forest products, agricultural products, and biological diversity (O'Connor 1984; Aplada et al. 2007). These ecosystems have special climatic as well as biogeographical features and hold a rich variety of ecological systems. The mountains create gradients of temperature, precipitation, and insolation because of their vertical dimensions. The ecosystems at the high elevations are strongly affected by climate, which gets cooler as elevation increases. We come across distinct vertical vegetation belts on high mountains due to their orographic conditions and climatic features (Grabherr et al. 1994; Lugo et al. 1999). The subalpine layer is the level between the upper forest boundary and the alpine belt (Beniston 1994; Körner 2003; Gungor 2011). It lies between the elevations of 1600 and 2000 m in the western Anatolian parts of

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Turkey. The features of flora and fauna in the mountains are dependent on the elevation, because of the change in climate. This dependency forms vegetation zones (Perry 1994; Price 1986). Temperature and precipitation conditions along this belt are different from those at the lower and middle parts of the mountain. The geology and soil formation conditions are the other factors playing a role in the formation of this special ecosystem (Curebal et al. 2012; Efe et al. 2012).

Few studies have been conducted on the vegetation, endemic species, and endangered plants of Kaz Mountain (Gemici et al. 1998; Ekim et al. 2000; Tumen et al. 2007; Dirmenci et al. 2007; Uysal 2010; Efe 2010; Ozturk et al. 2011; Efe et al. 2012). The subalpine zone of the Kaz Mountain is stocky, covered with sparsely scattered trees and some deformed woody taxa. The temperate forests of lowlands and foothills are replaced with bush and perennial species at higher elevations on this mountain, and above 1600 m the ecosystem is dominated by grasses, herbaceous, and stunted shrubs (Karabacak et al. 2006; Uysal 2010; Oztürk et al. 2010, 2011). Many different plant species such as grasses, sedges, and cushion or polster plants live in the subalpine environment of this mountain. These plants are adapted to the harsh conditions prevailing here, which include low temperatures, ultraviolet radiation, and a short-growing season. Black pine and Juniper are the typical trees which grow in montane forests. The soils originating from the weathered rocks are enough to support grasses and sedges. The biodiversity here is threatened by tourism as well as the collection of medicinal plants. Kaz Mountains are experiencing a severe environmental degradation.

This mountain lies in the northwest of Anatolia (Fig. 23.1). The topographic and geomorphological features of the mountain were recorded from 1/25,000 scaled toposheets and 1/100,000 scaled digital geological maps produced by Maden Tetkik Arama (MTA) and were used to understand the tectonic structures, lithological features, and soils of the area. The temperature and precipitation data were interpolated based on the elevation in order to find out the climatic features of the subalpine zone. The plant samples collected from the area were identified with the help of flora of Turkey and east Aegean Islands (Davis 1965–1985; Davis et al. 1988; Guner et al. 2000). The data obtained were compared with the vegetation belts of other neighbouring high mountains like Uludağ (Cepel 1978), Akdağ (Sonmez 2006), and Şaphane (Tel 2011).

23.2 Geographical Features

The study area is located on the coasts of the Gulf of Edremit, extending along the southwest-northeast direction, and the highest elevation is 1774 m. The main summits are Babadağ (1765 m) in the west, the Kırklar (1710 m) in the north, Nanekırı (1646 m) in the east, Sarıkız (1726 m) in the south, and Karataş (1774 m). The high mountain ecosystem is restricted to the areas above 1600 m, where the subalpine zone features are observed. It is composed of various igneous, metamorphic, and sedimentary rocks, but metamorphic rocks are more common; limestone and schist outcrop the subalpine zone, while limestone is exposed to chemical dissolution due

Fig. 23.1 Location of the study area on Kaz Mountain

to rains; schist undergoes physical dissolution and produces stacks of stones and blocks. Soil is very thin on the higher parts (Curebal and Erginal 2007). In some places, only the bedrock is present. Soil is either a little acidic or neutral.

Precipitation falls as rain and snow. Water flowing on the surface forms rivers and water infiltrates through diaclases feeds groundwater. There are some sources surfacing on contacts, slopes, and karstic areas. The subalpine zone of Kaz Mountain is rich in water (Soykan et al. 2008). Annual precipitation exceeds 1000 mm but lithological features lead to a ground drought.

Natural forest is located above 1600 m, but shows degraded features due to natural and human impacts. The winds are strong, soil is either not present or very thin, with sparse vegetation, and the trees are stunted. It includes the sacred hilltop called Sarıkız, visited by Turkomans for centuries. *Pinus nigra, Abies equi-trojani,* and polster plants constitute the dominating vegetation of the subalpine zone (Atalay and Efe 2010a, b).

The area is facing human disturbances for at least 5000 years from now, as it is located near the ancient Troy and Assos. This geomorphological mass, the ancient name of which is "Mount Ida", has an important place in the Greek mythology. "The Legend of Sarıkız", which emerged after Turks got settled in this region, indicates that the subalpine zone (i.e. the summit area) continues to attract people's attention (Bayat 2006). Thus, the natural forest cover has been damaged.

23.3 Plant Diversity

On the south-facing slope, *P. brutia* forests are widespread up to an elevation of 800 m followed by *P. nigra* zone. The zone between 1600 and 1774 m has subalpine and pseudo-alpine features (Pamukçuoğlu 1976). Average annual temperature difference between the coastal zone and higher altitudes is 8 °C, because the average annual temperature in Edremit is 16 °C, but drops to 8 °C around the summit. This creates a microclimate in which winters are frosty and snowy, and summers are cool.

There are three vegetation belts on this mountain. These are lowland, montane, and subalpine belts from bottom to top.

Lowland Zone This level goes up to 800 m above the sea level on the south slope. *P. brutia* dominates this level under an average annual temperature ranging between 12 and 16 °C. The amount of annual precipitation ranges between 650 and 1000 mm. The bedrock is composed of schist–limestone or granite. There are partially neutral and partially alkaline alluvial, colluvial, and brown forest soils.

The part up to 400 m has been damaged due to anthropogenic effects, and the area has been replaced by the shrubby maquis species. In some parts, olive groves have been established. The drought-tolerant plants found here are *Quercus pubescens, Q. ithaburensis, Q. infectoria,* and *Q. cerris*. The lowland zone on the north slope begins at an elevation of 100 m and goes up to 500 m. The original vegetation consists of an oak forest. The dominant species are *Q. frainetto* and *Q. petraea*. The average annual temperature on this belt ranges between 12 and 14 °C, and the annual precipitation ranges between 650 and 850 mm. The bedrock is composed of basalt. Soils are mostly neutral or low-acidic inceptisols.

Montane Zone This zone is mainly located on the south slope, between 800 and 1650 m and can be accepted as the black pine zone (*P. nigra*). The average annual temperature ranges between 8 and 12 °C, and the annual precipitation is 1000 mm at the lower level and 1450 mm at the higher level. The bedrock is composed of schist and Mesozoic limestones. Soils are low-acidic inceptisols (pH 6.5).

On the northern slope, this zone lies between 500 and 1650 m, mainly dominated by *Fagus orientalis* and *Abies nordmanniana* ssp. *equi-trojani* forests. The average annual temperature ranges between 12 and 16 °C, and the annual precipitation ranges between 850 and 1400 mm. The bedrock is composed of granite. Soils are low-acidic and acidic inceptisols (pH 5.5–6.5).

Subalpine Zone This area is located above 1650 m on the south slope and above 1600 m on the north-facing slope. It is accepted as the subalpine zone. There is no forest vegetation here. We only come across open areas covered with stocky and scattered trees, groups of bushes, and herbaceous plants.

23.4 Ecological Conditions of the Subalpine Zone

As the highest summit on Kaz Mountain has an elevation of 1774 m, it does not have an alpine level. However, the upper forest boundary lies between 1600 and 1650 m. There is a subalpine belt situated relatively between 100 and 150 m. The zone approximately covers an area of 10 km^2 (1000 ha). It lies along 4.5 km from east to west and 2.5 km from north to south. In short, the belt is narrow and the area is small.

The characteristics of the subalpine zone are the lack of a forest cover, yet the trees forming the forest become dwarf due to deformation. These scattered trees grow up to a certain elevation. The tree line is on the highest point they can reach. This shows that the subalpine zone is the zone between the upper forest boundary and the tree line. Above 1450 m, dwarf, spiny, and cushion-forming alpine plant species can be observed. Dwarf trees are accompanied by leaning and short woody plants with deformed trunks (Schmithüsen 1968).

The subalpine zone of this mountain is represented by dwarf black pine (*P. nigra*). These occur even on the highest summit at an elevation of 1750 m (Table 23.1).

The most common type of rocks in the subalpine zone is greenschist dating back to the Paleozoic Era. These are cleavage rocks which have got horizontally and vertically split by diaclases; therefore, they have undergone physical decomposition and have split into flat blocks of various sizes. It is said that these blocks are in an order (stone rings called "the atrium of goose" by the public) and that these formations are related to periglacial conditions. Bilgin (1969) also states that girland soils are present in the area. During the glacial period in the Pleistocene Era, the snow line in western Anatolia is said to have fallen up to 2200 m (Fig. 23.2).

Around the summit of this mountain, marble and schist occur in the same areas. The Sarıkız summit, which attracts attention due to its whiteness, is such a marble block; Babadağ and the Kırklar hills also show marble.

In the subalpine zone, the bedrock outcrops the surface and there is no soil cover in many parts. Shallow lithosols occur on severely eroded areas. As the area is high, physical actions such as sudden changes in temperature and frost effects help in the decomposition of rocks and as a result, blocks and gravels emerge. The dominance of rocks such as schist and limestone prevent the formation and development of soils. Due to the wind effect, deflation is strong in the area, which is composed of high plains. Thus, thin materials are wiped away and are not deposited.

Table 23.1 Fundamental ecological conditions, dominant vegetation, and species in the Kaz Mountain subalpine zone and other zones

Criteria	Slope	Vegetation zones		
		Subalpine	Montane	Lowland
Altitude	Northern	>1600	500–1600	100–500
	Southern	>1650	800–1650	0–800
Mean annual temperature (°C)	Northern	7–6	12–6	14–12
	Southern	8–7	12–8	16–12
Mean annual precipitation (mm)	Northern	>1400	850–1400	655–850
	Southern	>1450	1000–1450	667–1000
Bedrock	Northern	Schist, limestone	Granite	Basalt
	Southern	Schist, limestone	Schist, limestone	Schist, limestone, granite
Soil type	Northern	Podsolic	Limeless brown forest	Brown forest
	Southern	Podsolic	Limeless brown forest	Alluvial, colluvial, brown forest
Vegetation	Northern	Polster plants and mountain grass	Beech, fir forest	Oak forest
	Southern	Polster plants and mountain grass	Black pine forest	Red pine forest
Dominant species	Northern	*Acantholimon* sp. *Juniperus communis* ssp. *nana*	*Fagus orientalis*	*Q. frainetto* *Q. petraea*
	Southern	*Astragalus* sp. *Acantholimon* sp.	*Pinus nigra*	*Pinus brutia*

In the subalpine zone, the elevation causes changes in the precipitation and temperature, creating a different climate compared to that of the foothills of Kaz Mountain (Tables 23.2 and 23.3). As the mountain stretches in the east-west direction, the northern slope is prone to cold air masses. Therefore, the aspect is important. (Table 23.2).

The southern slope is warmer than the northern slope. While the average annual temperature of the south slope in the subalpine area is 7.6 °C, it is 6.3 °C on the northern slope. There are groups of Kazdagi firs on the north slope of the subalpine zone. The optimum average annual temperature for Kazdagi firs is around 8 °C (Efe et al. 2010). Since temperature conditions are not suitable for firs in the subalpine zone, the deformation in the forms of firs is observed.

A similar situation is present with black pines on the south slope, because the optimum average annual temperature required by the black pines is 10 °C, the subalpine zone is the lowest temperature limit for these pines. The subalpine zone of the study area is suitable for firs in terms of temperature, but the zone has marginal conditions for black pines (Efe et al. 2013a).

The amount of annual precipitation in the subalpine zone is around 1500 mm. The optimum annual precipitation required by the firs and black pines is 1400 and 1000 mm, respectively. Based on these data, it can be said that precipitation does

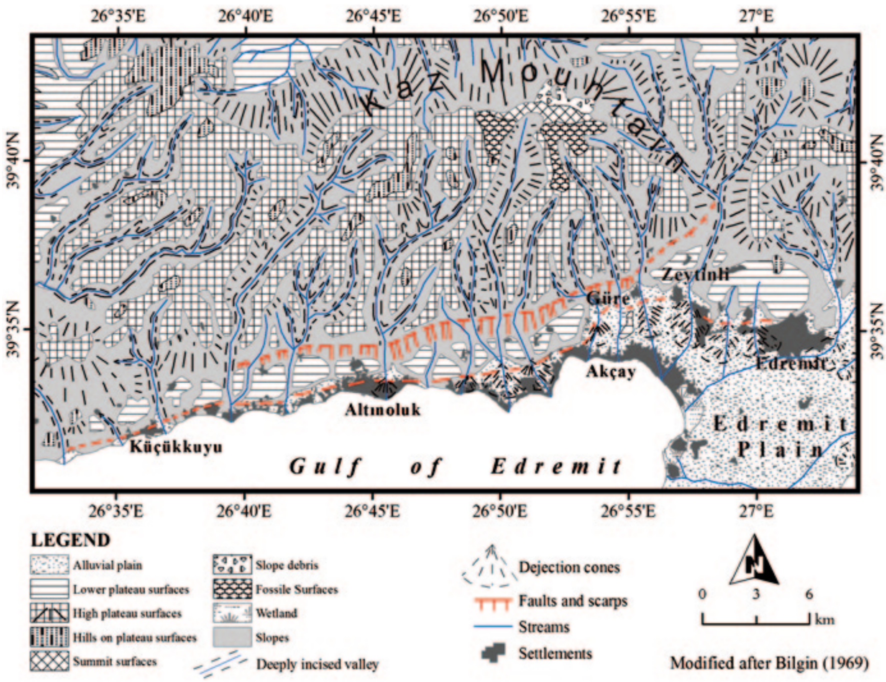

Fig. 23.2 Geomorphological map of Kaz Mountain

Table 23.2 The south slope of Kaz Mountain, temperature, and precipitation parameters of zones (Edremit meteorology station)

Months	Elevation levels (m)			
	Subalpine (1700 m)		Lowland (150 m)	
	(°C)	(mm)	(°C)	(mm)
January	−1.4	252.7	6.4	125.4
February	−0.8	225.5	7.0	98.2
March	1.2	132.7	9.0	75.3
April	5.7	108.1	13.5	50.7
May	10.8	94.8	18.6	37.4
June	15	22.6	23.1	14.3
July	17.7	13.5	25.5	5.2
August	17.2	12.9	25.0	4.6
September	13.6	85.4	21.4	20.1
October	8.2	119.2	16.0	53.9
November	3.5	177.6	11.3	112.3
December	0.5	266.4	8.3	139.1
Annual	7.6	1511.4	15.4	736.5

Table 23.3 The north slope of Kaz Mountains, temperature, and precipitation parameters of zones (Bayramiç meteorology station)

Months	Elevation levels (m)			
	Subalpine (1700 m)		Lowland (150 m)	
	(°C)	(mm)	(°C)	(mm)
January	−2.9	220.3	4.6	100.9
February	–2.0	202.6	5.5	83.2
March	0.1	129.5	7.6	67.3
April	4.6	114.5	12.1	52.3
May	9.4	106.8	16.9	44.6
June	14.0	40.1	21.5	25.4
July	16.2	25.6	23.7	9.8
August	15.5	23.8	23.0	8.0
September	11.8	91.7	19.3	29.5
October	6.8	103.1	14.3	40.9
November	2.6	152.1	10.1	89.9
December	−0.4	241.3	7.1	121.9
Annual	6.3	1451.4	13.8	673.7

not have an adverse effect on both species. Summer drought is not severe in this area.

When temperature and precipitation factors are considered, it is possible to say that there are suitable conditions for Kazdagi fir (*Abies equi-trojani*) in the subalpine zone. However, it is possible to state that the temperature conditions are not suitable for black pines (*P. nigra*). This unsuitability is also the primary reason why there is deformation in the pines.

The subalpine zone of Kaz Mountain is one of the main sources of rivers flowing towards the north and south in this region. The summit line makes up the watershed. Lithological structure has an important role in the leakage of water. Although schist is an impermeable rock, it has many diaclases around the summit area. The same is true for the marble. Moreover, marble and limestones are rocks that can dissolve.

The marble and schist outcrop in summit area increase the infiltration of water. Therefore, precipitation falling as snow and rain feeds groundwater rather than making up surface water. Water surfaces form strong and cold springs on both slopes. Zeytinli, Kızılkeçili, Fındıklı, Şahindere, and Mıhlı streams which flow towards the south and subsidiaries which join the Karamenderes and Tuzla streams by flowing towards the north feed from the subalpine zone of Kaz Mountain. There are about ten water springs in the subalpine zone, which are mostly contact springs. On the highest location is the Kartal spring or Kartalçeşme. It surfaces at an elevation of 1730 m and the source is formed on the schist–marble contact.

The subalpine zone is visited by many species of vertebrate mammals occasionally during their annual life cycle; including brown bears (*Ursus arctos*) which are the biggest mammals on the mountain. The habitats of these animals can be grouped into forest habitats, forest sides and polster plant habitats, herbaceous habitats, and rock habitats. Illegal hunting has lead to the disappearance of many species on the mountain (Table 23.4).

Table 23.4 Flora list of subalpine zone of Kaz Mountain

Scientific name	Family	Characteristics and form
Abies nordmanniana (Stev.) Spach ssp. *equi-trojani* (Ash. & Sint. ex Boiss.) Coode & Cullen	Pinaceae	Tree
Acantholimon ulicinum (Willd ex Schult) Boiss	Plumbaginaceae	Polster bush
Allium kurtzianum (Asch. & Sint. ex) Kollman	Liliaceae	Herbaceous
Armeria trojana Bokhari & Quezel	Plumbaginaceae	Herbaceous
Asperula sintenisii Asch. ex Bornm	Rubiaceae	Succulent herbaceous
Astragalus heldreichii Boiss	Fabaceae	Polster herbaceous
Astragalus idae Sirj (Geven)	Fabaceae	Polster bush
Asyneuma limonifolium (L.) Janch.ssp. *limonifolium* (L.) Janch	Campanulaceae	Herbaceous
Asyneuma virgatum (Labill.) Bornm. ssp. *virgatum* (Labill.) Bornm	Campanulaceae	Herbaceous
Centaurea athoa DC	Asteraceae	Herbaceous
Cerasus prostrata (Labill.) Ser var. *prostrata* (Labill.) Ser	Rosaceae	Bush
Chamaecytisus eriocarpus (Boiss.) Rothm	Fabaceae	Bush
Crataegus stevenii Porjark	Rosaceae	Bush
Crocus gargaricus Herbert ssp. *gargaricus*	Iridaceae	Geophyte herbaceous
Daphne oleoides Schreb. ssp. *oleoides* Scherb	Thymelaeaceae	Bush
Dianthus arpadianus Ade & Bornm	Caryophyllaceae	Polster herbaceous
Dianthus erinaceus Boiss. var. *alpinus* Boiss	Caryophyllaceae	Polster herbaceous
Draba bruniifolia Stev. ssp. *olympica* (Sibth. ex DC) *Coode et Cullen*	Brassicaceae	Polster herbaceous
Echium russicum J. F. Gmelin	Boraginaceae	Herbaceous
Ferulago idae N. Özhatay & E.Akalın	Apiaceae	Herbaceous
Genista anatolica Boiss	Fabaceae	Bush
Hypericum kazdaghensis Gemici & Leblebici	Clusiaceae	Herbaceous
Iberis saxatilis L	Brassicaceae	Polster herbaceous
Jasione idaea Stoj	Campanulaceae	Herbaceous
Juniperus communis L. ssp. *nana* (Hook.) Syme	Cupressaceae	Groundcover bush
Linum boissieri Asch. & Sint. ex Boiss	Linaceae	Polster bush
Minuartia garckeana (Asch. & Sint. ex. Boiss.) Mattf	Caryophyllaceae	Cluster herbaceous
Muscari bourgaei Baker	Liliaceae	Geophyte herbaceous
Papaver pilosum Sibth. & Sm. ssp. *strictum* (Boiss. & Balansa) Kadereit	Papaveraceae	Herbaceous
Parnassia palustris L	Saxifragaceae	Herbaceous
Paronychia sintenisii Chaudhri	Caryophyllaceae	Cluster herbaceous
Pinus nigra J. F. Arnold ssp. *pallasiana* (Lamb.) Holmboe	Pinaceae	Tree
Rosa pulverulenta Beib	Rosaceae	Bush

Table 23.4 (continued)

Scientific name	Family	Characteristics and form
Rosa sicula Tratt	Rosaceae	Bush
Saxifraga sancta Griseb	Saxifragaceae	Cluster herbaceous
Scabiosa columbaria L. ssp. *columbaria* L. var. *columbaria* L	Dipsacaceae	Herbaceous
Scilla bifolia L	Liliaceae	Geophyte herbaceous
Scutellaria orientalis L. ssp. *alpina* (Boiss.) O. Schwarz var. *alpina* (Boiss.) O. Schwarz	Lamiaceae	Cluster woody
Sedum album L	Crassulaceae	Succulent cluster herbaceous
Sedum dasyphyllum L	Crassulaceae	Succulent cluster herbaceous
Sedum lydium Boiss	Crassulaceae	Succulent cluster herbaceous
Sideritis trojana Bornm	Lamiaceae	Herbaceous
Silene bolanthoides Quezel, Contandriopoulos & Pamukçuoğlu	Caryophyllaceae	Cluster herbaceous
Silene falcata Sibth. & Sm	Caryophyllaceae	Cluster herbaceous
Thymus cherlerioides Vis. var. *cherlerioides* Vis.	Lamiaceae	Cluster woody
Thymus pulvinatus Čelak	Lamiaceae	Groundcover woody
Thymus sipyleus Boiss. ssp. *sipyleus* Boiss. var. *sipyleus* L	Lamiaceae	Groundcover bush
Trifolium fragiferum L. var. *fragiferum* L	Fabaceae	Cluster herbaceous
Tulipa sylvestris L	Liliaceae	Geophyte herbaceous
Veronica chamaedrys L	Scrophulariaceae	Cluster herbaceous
Viola tricolor L	Violaceae	Herbaceous

23.5 Vegetation

On the south-facing slope of the subalpine zone, there are degraded, deformed, and dwarf coniferous trees, cushion-shaped bushes, and herbaceous plant communities.

23.5.1 Degraded Coniferous Forests

This degraded community is composed of *P. nigra* on the south slope, which is distributed between 1650 and 1774 m. The cover is sparse, trees are dwarf and deformed due to low temperatures, strong winds, and unsuitable soil conditions. Average annual temperature on this slope of the subalpine zone is 7.6 °C, which is the marginal temperature for black pines. The optimum average annual temperature for black pines lies around 12 °C (Efe et al. 2013b).

The average annual temperature on the northern slope of the subalpine zone is 6.3 °C, and here we find black pines and Kazdagi firs which are dwarf-shaped

(Table 23.3). Short and single black pines can be observed up to 1690 m, while Kazdagi firs can be observed up to 1600 m. Although the precipitation on the north slope of the subalpine zone is enough, low temperatures have an adverse effect on tree growth. Both tree species found here can endure low temperatures (− 20 to − 25 °C). However, the summer temperatures required for the growth of these trees are not enough in terms of duration. Therefore, these trees are stunted in appearance, and effective winds deform these (Tables 23.2 and 23.3). The vegetation period for broadleaved tree species is very short, so they are not observed in the area.

23.5.2 Woody Bushes and Cushion Plants

These are leaning woody plants as bushes with xeromorphic appearance and are hardly ½ m tall. Their distribution is different on the north and south subalpine slopes. The most common and characteristic one is *Juniperus communis* ssp. *nana,* a ground-cover tree, very common and dominant in the northern section, but their number decreases towards the south. Junipers characterize the subalpine zone of Kaz Mountain (Pamukçuoğlu 1976).

Daphne oleoides is another common species, occurring as short and cushion-formed group. Its wood is hard, leaves are fleshy and hard. They are widely distributed but decrease in number towards the south.

Astragalus idea is the typical representative of the south of the mountain subalpine zone (Tümen et al. 2007). They form groups in some places and decrease in number towards the north.

Acantholimon ulicinum grows on the driest habitats of this zone, is common on the north slope but decreases in number towards the south. These plants are cushion like, xeromorphic, and are widely distributed.

The species like *Cerasus prostrata, Crataegus stevenii,* and *Chamaecytisus eriocarpus* are sparsely observed. The species of roses *Rosa canina, R. pulverulenta,* and *R. sicula* are other stocky bushes growing in the area. Three bushy thyme species found here are *Thymus cherlerioides, T. pulvinatus,* and *T. sipyleus*. These are found in the middle and southern sections of the subalpine zone. *Linum boissieri* is a calcicole woody plant which has been recorded from the area (Table 23.4) (Fig. 23.3).

The zone on the whole experiences highly effective winds; woody plants take different shapes. They leaned or form groups or cushions. The dry habitats, insufficient temperatures, shortness of the vegetation period, and thin soil cover or no soil cause these plants to remain short and develop xeromorphic characteristics.

23.5.3 Herbaceous Species

There is a grass cover (meadow) at the subalpine level of Kaz Mountain, which is common even among the bushes, in some large treeless areas, where winds are most effective and grounds are rocky with very thin soils; the grass cover is defined as

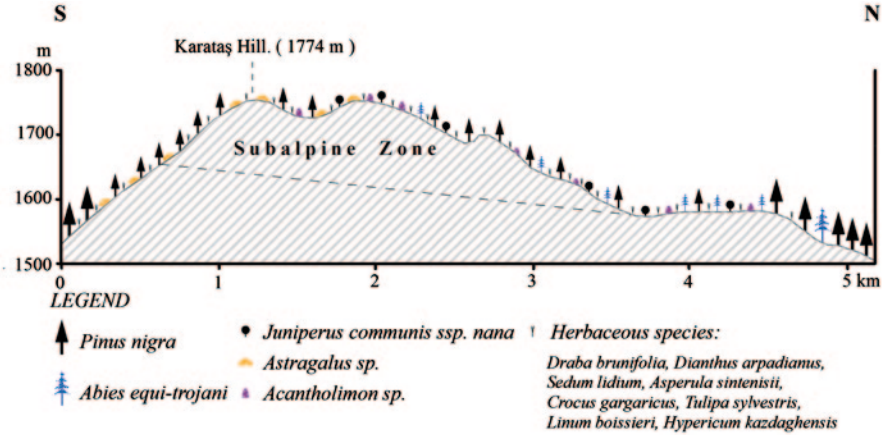

Fig. 23.3 Vegetation cross section of the subalpine zone of Kaz Mountain

"pelouses ecorchées" (Efe 1998). The vegetation is generally buried under the snow cover in winter. It reappears in the beginning of April, and functions until the next snowfall. However, the vegetation activity season of each species differs. The grass cover creates a pleasant landscape in the subalpine zone.

Most of grasses are lithopytic and chasmophytic, clinging to rock surfaces and fractures. *Dianthus arpadianus* and *D. erinaceus* var. *alpinus* are the typical examples of this cover. *Draba brunifolia* ssp. *olympica* is a calcicolous plant distributed on the Sarıkız hill, a typical chasmophyte.

Some succulent grasses with fleshy leaves are also found in the area. *Sedum album, S. dasyphyllum, S. lydium,* and *Asperula sintenisii* too are abundant in this area. The geophytes like *Crocus gargaricus* and *Tulipa sylvestris* are appearing in spring, summer, and fall (Fig. 23.4).

There are 24 endemic species belonging to 15 families distributed in the study area (Table 23.5), out of these 9 are endemic to Kaz Mountains, and 15 are endemic to Turkey. These mostly occur at elevations between 1700 and 1750 m (Table 23.5). Some species such as *Dianthus erinoceus* var. *alpinus, Ferulago idea, Linum boissieri,* and *Silene bolanthoides* grow only on limited areas in the subalpine zone.

23.5.3.1 Anthropogenic Effects on the Subalpine Zone

Kaz Mountain and the surrounding area have been used by the humans for thousands of years. Troy, Adramytteion, Thebe, Astyra, Antandros, Gargara, Assos, Lamponia, Scepsis, Scamandria, Kergene, Kebrene, Pionia, Kergis, Troas, Neandria, and Argisa are the ancient cities situated around this mountain (Efe et al. 2014). Troy dates back to 3000 BC (Rix 2002; Umar 2002), which depicts that this area is settled for at least 5000 years.

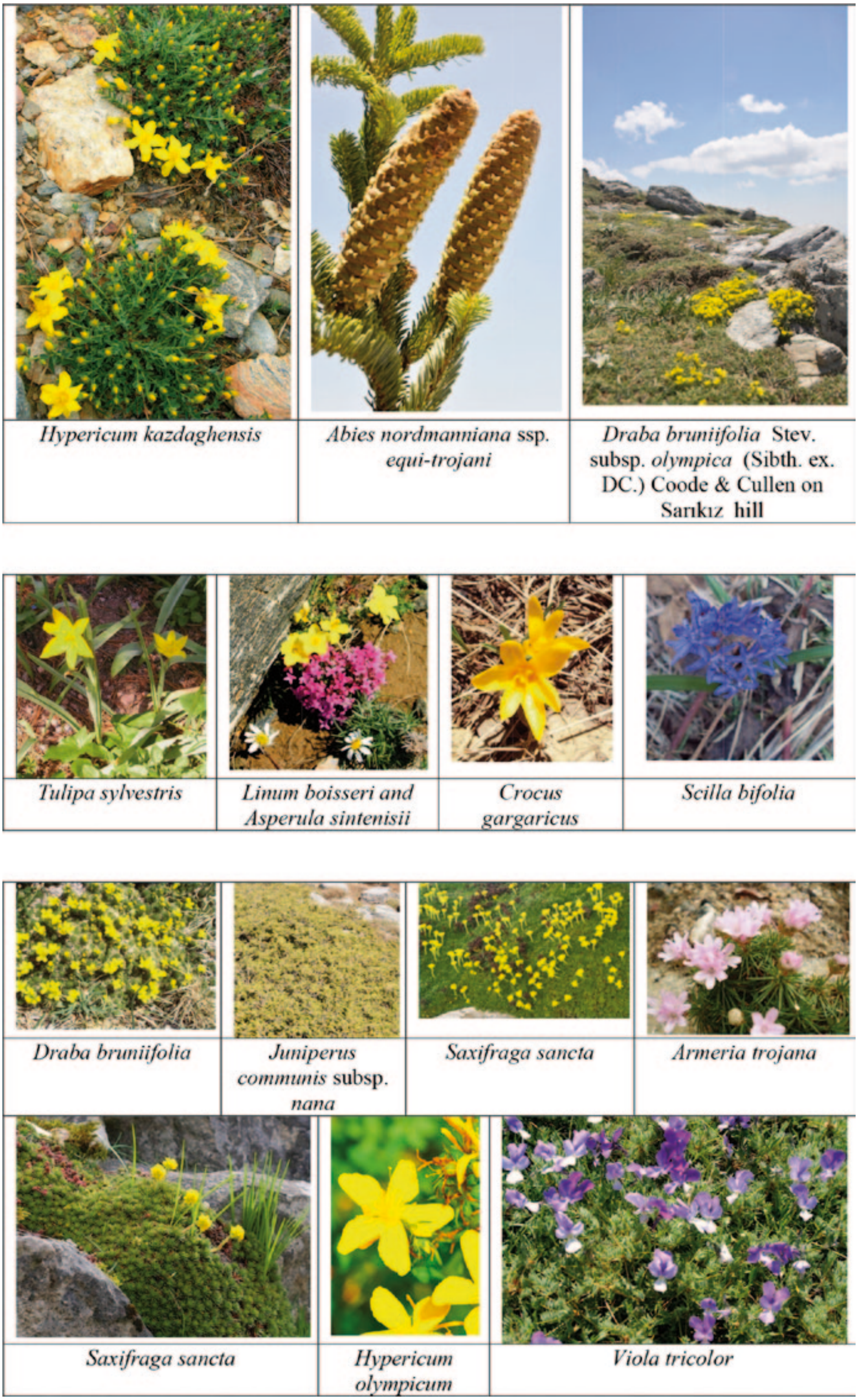

Fig. 23.4 Plant species on the higher parts of Kaz Mountains

People have known Mount Ida for thousands of years and have benefitted from it in various ways. The mountain has mostly been used for timber and animal husbandry purposes.

Goat, sheep, cattle, and horse herds have been fed since the early ages of history. Among the findings belonging to the ancient cities of the region, we come across the coins with the figures of the above-mentioned animals (Serdaroğlu 2005). Undoubtedly, this mountain has been used as a highland for thousands of years. The fact that cheese making of the region is very popular can be regarded as a result of traditional animal husbandry.

After Turks (Oghus Turks—semi-nomadic tribes) arrived in the region, these activities became even more intense. An overuse of mountain meadows has damaged the floristic composition and weakened the vegetation. Composition of the vegetation varies with landscape position, aspect, and grazing history. Field studies have revealed that very spiny, bulbous, extremely aromatic, and even poisonous grass species are common than forage.

Timber trees including black pine, fir, beech, and chestnut are common on the northern slopes. These trees have been cut down for various purposes for thousands of years (Özdemir 2008). Local people have enshrined Mount Ida since ancient times. This enshrinement has continued with the “Legend of Sarıkız”. The area of Sarıkız stands like a pyramid in the subalpine zone of Kaz Mountain. Yellow wild flowers blossom around this area in spring. Many years ago, people of Güre and Kavurmacılar villages used to go to Sarıkız hill, and this tradition spread to other villages in the area. Today, an annual festival is celebrated here, attributed to Tahtacı and Çetmi Turkomans living in the region.

There were many historical paths in the subalpine zone of Kaz Mountain. These are connected to Bayramiç and Kalkım districts in the north. Roads beginning from Altınoluk and Zeytinli in the south and going up to the summit have been used in the past. All these present the evidence for an immense anthropogenic effect on the subalpine zone of Kaz Mountain.

23.6 Climate Change Impacts

Our findings show that a periglacial section has emerged in the Kaz Mountain during the Pleistocene period. These periglacial marks have reached even up to the modern times (Bilgin 1969). During that period, snow line in the West Anatolian part of Turkey shifted down to 2200 m (Erinç 1971). It dropped to around 1650 m in the Periglacial zone of Kaz Mountain, which has a tundra-like appearance and vegetation, is composed of arctic-alpine elements. The upper forest line fell to 1650 m, which is the lower limit of the periglacial layer. The lower forest line of this boreal forest is made up of coniferous tree species up to 1200 m. *Abies nordmanniana* ssp. *equi-trojan*i, an endemic coniferous species found only on this mountain, appeared under the conditions of that period. In the past, these firs were more widely distributed, but their area has gradually shrunk in size due to temperature increases following the global warming.

The subalpine zone in the Kaz Mountain found today is an outcome of the effects of orographic factors. The area of firs decreased and beech community took shelter on the northern slope. *Rhododendron flavum* species spread in the area during the Pluvial period, and existed in the form of small groups as relicts in areas dominated by special edaphic conditions.

Due to the climate change, it is difficult for the vegetation belts in the Kaz Mountain to move upwards as a whole; however, local shifts are expected. A 2 °C increase in temperature equals to a difference of 400 m in altitude. As a result, some competitive plant species growing in lower parts will come to the upper zone and there will be an extinction of plant species in some areas. *P. brutia* can be expected to reach 1000 m, whereas *P. nigra* and *Abies nordmanniana* ssp. *equi-trojani* are likely to go up to 1100 and 1500 m, respectively.

The global warming will destroy the subalpine zone, leading to a decrease in the Kaz Mountain fir zone. This species will move towards higher and more secluded areas and perhaps disappear. The lower limit of the beech zone too will go higher, and its area will get narrower. Meanwhile, hygrophilous species will decrease in number, and the hygrophilous flora may get lost. *Rhododedron flavum* is likely to fail to flourish in the area.

The vegetation on the northern slopes will lose its hygrophilous characteristics, and the flora will be deprived of its richness. The southern slope will be even warmer. The upper limit of *P. brutia* will reach up to 1200 m. *P. nigra* will only be able to grow above this level and cover each and every corner up to the summit. They will reach the northern slope and be the only dominant element there. The vegetation will assume even more xerophytic characteristic, and the flora will be poor. Xerophytic species with an affinity for high temperatures will prevail in the area.

23.7 Conclusions

Mountainous regions are more prone and sensitive to climate changes. Thus, these fragile ecosystems must be analysed better than other areas, and expected damage due to climate change must be minimized. There is a subalpine or pseudo-alpine zone, formed by natural factors in the area above 1650 m on Kaz Mountain. Climate, elevation, and bedrock are the main factors determining the features of this zone. There is a difference between the northern and southern parts of the mountain in terms of the amount of precipitation and temperature. The north slope receives more precipitation, and the average annual temperature on the north slope is 1.3 °C, colder than that of the south slope. The average temperature of the coldest month is −1.4 °C on the south slope and −2.9 °C on the northern slope. A large amount of snow falls in winter, and the amount of annual precipitation reaches 1500 mm in the area. Rocks cut through by diaclases increase infiltration. Thus, the area is rich

Table 23.5 Endemic plant species in subalpine zone in Kaz Mountain (Mount Ida)

Name of the taxon	Family	Habitat and altitude (m)
Abies nordmanniana (Stev.) Spach ssp. *equi-trojani* (Asch.& Sint. ex. Boiss.) Coode & Cullen[b]	Pinaceae	1000–1700 m Northern slope
Allium kurtzianum (Asch. & Sint. ex) Kollman[b]	Liliaceae	1500–1750
Armeria trojana Bokhari & Quezel[b]	Plumbaginaceae	1500–1700
Asperula sintenisii Ascherson ex Bornm[b]	Rubiaceae	1600–1750
Astragalus idae Sirj[b]	Fabaceae	1600–1750
Astragalus heldreichii Boiss[a]	Fabaceae	1300–1700
Asyneuma virgatum (Labill.) Bornm. ssp. *cichoriiforme* (Boiss.) Damboldt[a]	Campanulaceae	700–1700
Corydalis wendelboi Lidén ssp. *congesta* Lidén & Zetterlund[a]	Papaveraceae	700–1700
Crocus biflorus Miller ssp. *nubigena* (Herbert) Mathew[a]	Iridaceae	200–1700
Crocus gargaricus Herbert ssp. *gargaricus*[a]	Iridaceae	1300–1700
Dianthus erinoceus Boiss. var. *alpinus* Boiss[a]	Caryophyllaceae	1700
Ferulago idea N. Özhatay & E. Akalın[b]	Umbelliferae	1750
Hypericum kazdaghensis Gemici & Leblebici[b]	Hypericaceae	1500–1700
Iris kerneriana Asch. Sint. ex Baker[b]	Iridaceae	900–1700
Jasione idaea Stoj[b]	Campanulaceae	1350–1700
Linum Boissieri Asch. & Sint. ex Boiss[a]	Linaceae	1700
Muscari bourgaei Baker[a]	Liliaceae	1500–1700
Muscari latifolium Kirk[a]	Liliaceae	1100–1750
Onosma bracteosum Hausskn.& Bornm[a]	Boraginaceae	300–1700
Onosma nanum DC[a]	Boraginaceae	0–1700
Sedum lydium Boiss[a]	Crassulaceae	1500–1700
Sideritis trojana Bornm[b]	Lamiaceae	1500–1720
Silene balanthoides Quezel, Contandriopoulos & Pamukçuoğlu[b]	Caryophyllaceae	1700
Stachys tmolea Boiss[a]	Lamiaceae	200–1700

[a] Endemic to Turkey
[b] Endemik to Kaz Mountains

in surface and groundwater and springs. Slope and contact sources are common in the area.

Metamorphic rocks such as schist and marbles and granitic rocks are common in the area. Physical dissolution occurs in the subalpine zone due to daily and seasonal temperature differences. Soil cover is thin, and soils are acidic. Due to natural and anthropogenic erosion, bedrock has surfaced in many sections on higher parts of the mountain.

Black pines occur up to the summit of the mountain in the subalpine area. However, they are short and deformed. Kazdagi firs (*Abies equis-trojani*) occur on the north slope. On the south slopes, there is a plant community consisting of cushion-forming species, tufts of grasses, perennials, and dwarf woody species. The dominant member of this community is *Juniperus communis* ssp. *nana*. Groups of herbaceous plants and geophytes are abundant on rocky surfaces and between cracks. The area is also rich in endemic species. The cushion-formed bushes, herbaceous, and other plants in this community are defined as a subalpine meadow or pelouses ecorchées.

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Chapter 24
Patterns of Development of Mountain Tourist Centers In Bulgaria

Mariana Assenova, Vasil Marinov and Vasya Yaneva

24.1 Introduction

In Bulgaria, as in established tourism destinations, summer mountain recreation and hiking first started to develop at the end of nineteenth century, but like in France, Italy and other countries, the purposeful planned development spread initially at the Black Sea coast, and then the focus was transferred to the development of mountain winter tourism, although on a smaller scale and at a slower rate (Evrev 1987). The advantage of mountain areas is that they offer opportunities for recreation both in summer and winter, and the tourist season is significantly longer than at the seaside. Moreover, their carrying capacity is assessed to be 50 % higher than at the Black sea coast (Evrev 1999).

Bulgarian mountains, as morphological structures, cover about 48 % of the national territory (Michailov 1989) and the mountain areas above 600 m occupy about 28 % of its territory. Medium and high mountains (above 1000 m) represent about 12.5 % of Bulgarian territory. In Rila, Pirin, Vitosha, and Western Rhodopes the areas with an altitude above 1000 m comprise between 60 and 70 % of them (Evrev 1987). Mountains in Bulgaria have excellent conditions for summer recreation, hiking, and mountaineering. They provide good conditions for quality ski terrains with significant elevation differences and varied configuration of slopes, and stable snow cover between 80–150 days in the medium height zone and 160–250 days

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in the alpine zone. The length of the season with favorable climatic conditions is 8–9 months a year. In addition, 50–70% of the specified territory is covered by deciduous and coniferous forests; in the alpine zone there are numerous beautiful alpine lakes and peaks, creating a pleasant environment for walking and hiking, while mountain rivers are suitable for fishing. Furthermore, mountains are included in the majority of protected areas and natural landmarks that enhance the quality of environment for tourism and recreation,and pose higher requirements for its conservation. At the foot of the mountains, many spa facilities are concentrated that complement the leisure and recreation supply offers, especially when combined with the rich heritage of archaeological, architectural, and historical monuments in the mountain villages and the ethnographic characteristics, traditions, and lifestyle of mountain people.

The current chapter presents the preliminary results of a planned long-term and detailed study of tourism development in Bulgarian mountain territories and should be regarded as an initial phase of a large-scale survey with expected expanding of the research methods and instruments, including future field research.

24.2 Study Area

The present study is based on the identification of tourist centers located in mountain areas and for that reason the terminological determining of a mountain territory is of primary importance. Criteria for determining mountain areas are different in different countries, but always include altitude, although with different values in different countries, often depending on their latitude (France—600–800 m, Switzerland—1000 m, Greece—800 m, Italy—600 m, Spain—1000 m, Slovakia—600 m). Other (modified) criteria include slope inclination (France, Spain, and Slovakia) and relative elevation (Italy) (Marinov and Assenova 2008).

In identifying the mountain tourist centers in Bulgaria for the purpose of this research, the understanding of Evrev (1987) was accepted that from the point of view of mountain tourism and recreation only areas with an altitude above 600 m should be considered, but some deep incised valleys and settlements within them must also be attributed to the mountain areas despite their small altitude. This means that the territories for mountain tourism and recreation in Bulgaria include parts of Rila, Pirin, the Rhodopes, Western and Central Stara Planina, Vitosha Mountain, Osogovska Mountain, and Sredna Gora Mountain with altitude above 600 m. Undoubtedly, other lower mountains of the country are also important for the development of tourism and recreation, especially Strandzha, Eastern Rhodopes, Eastern Stara Planina, etc., but their altitude and their modest tourism and recreational resources, as well as their location, do not justify their recognition as areas for mountain tourism development (Evrev 1987).

Being an activity with a strongly expressed spatial aspect and spatial impact, tourism creates specific spatial formations, due to the localizing character of the tourism resources (attractions), the facilities, and the tourist flows. In the tourism space there is a combination of elements which are different in their nature, scale, hierarchy, and dynamics. Among them of big importance are the tourist centers (locations, villages) as the "crystallizing point" of the recreational demand (Kaspar 1991)—that part of the tourism space, in which the greatest mixture, complexity and intensity of all basic elements of the processes of tourism and recreation are observed and which, at the same time, is the most appropriate object for an effective tourism planning (Marinov et al. 1998).

The mountain tourist center can be a settlement or settlement formation[1] (resort complex, holiday village, or villa zone), either with the status of a resort or resort locality, or not officially announced as such, and is regarded as a compact territorial unit for tourism and recreation of the lowest rank in which the elements of the territorial system of tourism and recreation can be distinguished.

The number of mountain settlements (both towns and villages) in Bulgaria, suitable for tourism and recreation, is over 300 and in the mid-80s 130 of them already have available accommodation facilities (Evrev 1987). These settlements have developed as resorts and nearly half of them are officially declared resorts of national or local importance. The mountain settlement formations represent a broad network of resort complexes, holiday villages, and villa zones, and their available beds are distributed in different proportion in hotels, chalets, individual villas and other.

24.3 Methodology

The scope of the study is based on existing models of the processes and typologies of tourist development (e.g., Pearce 1991; Marinov 2002; Yurukova 2012, etc.) as well as destinations' lifecycle and the related impacts of tourism (Butler 1980; Buhalis 2000, etc.).

The aim of the study is to identify and briefly analyze the existing tourist centers in mountain territories and to draw some hypotheses about the patterns of development of mountain tourist centers in Bulgaria. The approach applied to derive the patterns of tourism development is based on comparing the identified tourist centers against a number of selected criteria, set in three groups helping to outline their structure. The criteria used to reveal their *physical structure* include genesis and type (settlement or settlement formation, either resort or not), altitude and size, environment (tourist resources in use and specialization), spatial structure (planning and development), and capacity of tourism facilities. The *economic structure* is outlined based on the level of tourism development and market significance, type of privatization and property structure, origin of investment (endogenous and exogenous), distribution of costs and benefits of development, and management and

[1] Under the Law on Administrative and Territorial Division of Bulgaria (2011) settlement formations are areas outside the construction boundaries of the settlements, established to carry out specific functions of local or national importance, within specific clearly defined boundaries and development plan, but without permanent population.

marketing of the centers. The *sociocultural structure* is evaluated on the basis of the origin of employees, local community involvement, etc. For each of the criteria studied, 3–5 distinct categories are defined, making it easy to assign each of the centers to a specific category.

The chronological approach is also applied to study the path of mountain tourism development in several consecutive periods and the key features of each period are pointed out including both the positive and negative aspects of development.

The methodology of the study is based on the combined use of different methods of collection, processing, and analysis of information on the characteristics and the development of mountain tourist centers and destinations. The specific methods that have been applied in the study include:

- Review and systematization of the scientific literature, directories and internet resources, planning and legislative documents, official reports and statistics at regional and municipal levels, etc. in regards of mountain tourism development and certain tourist centers.
- Detailed study of the public national register of accommodation facilities, categorized by the state and municipal authorities to derive quantitative and factual information about the identified tourist centers.
- Interviews with owners or concessioners of tourism facilities and infrastructure, as well as municipal authorities' representatives.
- Statistical methods for processing quantitative information.
- Scientific analysis and synthesis of primary and secondary information.

24.4 Results

24.4.1 Former Studies of Mountain Tourism in Bulgaria

In the 90s of the previous century Bulgarian Academy of Sciences conducts a detailed research on natural and economic potential of the Bulgarian mountains (Mishev et al. 1989), including morphometric and morphogenetic characteristics of mountains and component analyses of their natural resources, as well as agroclimatic and recreational potential. Separately, natural resources for economic development and recreation of Rila Mountain are evaluated (Stoychev and Petrov 1981). The issue of spatial planning and development of mountain resorts is thoroughly studied by Evrev (1987, 1999).

The development of tourism in the fastest-growing mountain center in Bulgaria—Bansko—is traced from the mid 90s through a series of studies and subsequent publications (Marinov et al. 2000a). Special attention is paid to the study of tourism demand in the same region (Marinov et al. 2000a, 2000b) with the intention to develop a regional information system for its monitoring. With focus on a single mountain resort is the research of Yaneva (2009a, 2000b) outlining key issues and long-term prospects of a new project for a large mountain center—Super Borovets, aimed at territorial expansion and renovation of the tourist product of Borovets national ski resort.

A detailed review of mountain tourism development in Bulgaria is made by Kazachka and Dogramadjieva (2006, 2007), which demonstrates that its share in national tourism development is considerable—25 % of the accommodation facilities, 12 % of available beds, 13 % of the visitors, 8 % of the overnights, and 5 % of the income from accommodation. Worth mentioning is the conclusion provided that the three biggest tourist centers in the mountains—Borovets, Pamporovo, and Bansko comprise about 40 % of the bed capacity, 56 % of the overnights, and 72 % of the total income generated in mountain centers. The quantitative parameters of supply and demand are derived by aggregating data on accommodation establishments used primarily for mountain types of tourism in each municipality.

Typologies of settlements with a pronounced tourist function in Bulgaria are prepared by Bachvarov (1986) and by Marinov and Bachvarov (1990). According to the latter, 42 settlements are identified as mountain tourist centers. Bachvarov (1991) identifies 760 settlements and settlement formations (complexes) with a tourist function; however, mountain centers are not explicitly specified and it is emphasized that in most of these settlements the tourist function is weak.

Several studies are carried out on typology of tourism development at municipal level (Marinov 2002; Yurukova 2012, etc.). The typologies of municipalities in the country are based on dominant tourist centers and types of tourism. According to the typology from 2002, the municipalities dominated by mountain tourist centers are 33, out of them 5 are dominated by large tourist centers and the rest 28—by smaller ones. The updated typology from 2012 indicates that the municipalities with mountain resorts are 25 in total, 4 of them being dominated by large mountain resorts, and the total number of mountain centers considered is 59. In terms of magnitude of tourism development in 2010, municipalities with large ski resorts come second following the coastal municipalities and those with smaller mountain resorts have marginal importance. The figures indicate the dynamic character of territorial development and the appearance and dominance of other types of tourism, respectively other tourist centers.

Such a typology of the country at lower territorial level (tourist centers) has not been worked out so far due to statistical limitations—no official statistics is available on that lowest level.

24.4.2 Identification of Contemporary Mountain Tourist Centers

The scientific literature has repeatedly drawn attention to the discrepancy between the official resorts and the actually existing settlements and localities performing recreational functions (Marinov 1993). Depending on the medical and prophylactic resources utilized, the officially proclaimed resorts are divided into spa (balneology) and climatic (seaside and mountain) resorts. As already mentioned some of the mountain tourist centers are officially declared resorts, the first of them being

Table 24.1 Officially declared resorts in Bulgaria (1975–2012)

Type of resorts	1975	1991	1992	2012
Seaside climatic resorts	28	28	28	34
Mountain climatic resorts	62	77	58	55
Balneology resorts	55	61	57	54
Total	145	166	143	143

Borovets announced in 1948. As of 1975 Bulgaria has 145 resorts (Table 24.1). Over the next 15 years another 21 new resort of local importance have been announced. In early 1992 some resorts (mainly mountain climatic resorts) are delisted, resulting in a total number of 143 resorts (Marinov 1993). Their total number nowadays is retained with some changes in the ratio between the types of declared resorts.

The mountain climatic resorts are 55 but some of the balneology resorts (22) are also located in the mountains at an altitude above 600 m; thus, the total number of mountain tourist centers, which are officially declared resorts, is 77. It is necessary to be clarified that some of the mountain resorts are located lower than 600 m, but they are included in the final list due to their official resort status.

The Trade Unions' establishments before the changes in 1989 have also been divided into and managed as resorts complexes "Recreation and resort therapy", each of them comprising individual resorts, tourist facilities, and tourist localizations (Apostolov et al. 1983). The total number of resorts in 1983 is 78, divided into 35 complexes. Out of them 37 are mountain tourist resorts and only 10 are different from the officially declared resorts.

To ensure the needs of short-term holidays a significant number of recreational zones have been established till 1990. They are set to perform mixed functions serving both long-term vacations and short holidays, but the forms of short rest predominate. These are mostly natural or forested parks, forest localities, artificial lake coasts, river valleys, etc. (Brambarov 1990). The majority of them are visited for overnight stay, but day visits without overnight stay for various sports and cultural tourism activities are also popular. The facilities mainly include chalets, holiday homes, motels and campgrounds, hunting and fishing facilities, facilities for winter and water sports, shops and restaurants, etc. The total number of recreational zones in 1990 is 331, out of them 90 are located at an altitude greater than 600 m.

Detached mountain chalets are not regarded as separate tourist centers. From the mountain chalets, managed and supervised by the Bulgarian Tourist Union (232 in total), only those are considered as tourist centers which provide available technical infrastructure for winter sports, namely 25—equipped with ski runs, ski lifts, and drags.

The detailed list of villages, resorts, and natural environments for recreation, tourism, and resort therapy, elaborated by the state Integrated Research and Design Institute for Regional Planning, Urban Planning and Architecture (1987) has also been thoroughly studied. The list comprises about 1400 sites distributed by districts, and their main function as well as the types of tourism, based on the available tourism resources, is indicated. Specially considered are not only the sites for long-term climatic recreation, exceptionally for tourism but also the villages and places specified as "complexes" (i.e., settlement formations). Out of the list altogether 133 sites are identified as nowadays mountain tourist centers and 27 of them have not been included in the previously commented lists of centers.

Mountain tourist centers, as already pointed out, are established both as parts of settlements or as independent settlement formations, the second regarded as mono-functional and integrated in character. The settlement formations are expected to be officially declared with clear boundaries as required by the legislation and respectively included in the official list of settlements and settlement formations. In this relation an attempt was made to study the official register of mountain settlement formations with the unsatisfactory result that the number of the legitimate ones is only six—one of them (Borovets) being of national importance and the rest are of local importance. The described situation means that many of the settlement formations either exist unofficially or their absence from the official register is due to the unconcern of national and local authorities to submit timely adequate information as required by the law.

After detailed review of the official and actually existing resorts and recreational zones, a list of 199 mountain tourist centers has been compiled for further study and analyses. They fall in 71 municipalities. The highest concentration of centers is observed in Smolyan Municipality (18 centers) and 28 municipalities have only 1 distinguished mountain center. Another 16 municipalities (22,5 %) have 2 mountain centers on their territory, 20 municipalities (28,2 %)—between 3 and 5 centers, and 6 municipalities (8,5 %)—between 6 and 10 centers.

24.4.3 Characteristics and Patterns of Development of Mountain Tourist Centers

At the current phase of the research, the available data allows more detailed characterizing of the physical structure of the mountain tourist resorts but general idea of their economic and sociocultural structure is also outlined.

Genesis and Statute About 39 % of the mountain tourist centers consist of officially declared resorts. The categorization of official resorts and resort localities reflects the particular importance of resources, that is, their health and medical aspect, but not the level of development of the spa treatment and tourism or regional origin of visitors. No requirements are set for the state of resort facilities, infrastructure, public works and outlook, availability of qualified medical personnel, etc. Particularly problematic are the criteria for distinguishing the resorts of national and local importance. As pointed out, the mountain tourist centers officially declared as resorts are 77, the rest 122 are often referred as such but do not have the official resort status.

In the list of the official resorts 55 are mountain climatic resorts and 22 balneology resorts, 51 are resort settlements, 26 are resort localities, 9 are of national, and 68 are of local significance. All the resort localities with just one exception are mountain resorts—two of them of national (Borovets and Pamporovo) and 25 of local significance.

The announcement of resorts in Bulgaria has been sporadic with several periods identified for considerable increase of their number. The first resort in the mountains—Borovets—has officially been proclaimed in 1948, followed by two balneology resorts—Velingrad and Narechen—declared in 1950. For more than a decade no other resorts in the mountains are added to the list, but the activation in the 60s resulted in the announcement of 78 % of all the resorts in the mountains with a peak in 1963, when more than half of all the resorts have been declared. Afterward the process developed at slower pace with about 10 % of the resorts proclaimed in the 70s, about 5 % in the 80s, while in the 90s and after 2000 the list is extended by only one resort.

Type The criterion reflects the administrative and organizational aspect of tourist centers. Mountain centers are either independent out-of-settlement complexes and settlement-like formations and zones (Borovets, Pamporovo, Tsigov Chark, Yundola, Zelin, etc.) or pure settlements. The resort complexes and the other out-of-settlement formations, namely holiday villages and villa zones, are treated like settlements in terms of their spatial planning and organization, but they do not have the status of settlement. Among the mountain tourist center, 40 % are out-of-settlement formations, but as commented above only six of them have the official settlement-like formation status. The rest of the mountain centers are settlements, represented by villages (43 %) and towns (17 %).

Altitude The very high mountain centers (above 1800 m) are relatively few—4 %, which are entirely established in out-of-settlement environment and are mainly developed next to mountain chalets (Fig. 24.1). The high mountain centers (1300–1799 m) represent 22 % of all the centers and with a few exceptions they are out-of-settlement formations (93 %), developed as integrated mono-functional specially constructed resorts (Borovets and Pamporovo), small ski centers close to mountain chalets or summer holiday and hiking centers. Medium-height centers (1000–1299 m) account for 28 % of all centers and are widely represented by both settlement-like formations (35 %) and settlements (65 %). Settlements entirely dominate the centers in the hypsometric belt 600–999 m (88 %), particularly typical for the Stara Planina Mountain and the Rhodopes and also characterized by the large representation of spa and balneology centers (25 %). In fact 86 % of the balneology centers in the mountains are concentrated in the specified belt. The very low mountain centers (below 600 m) are 9 % and every forth of them is an out-of-settlement formation, while 65 % of them are towns. Therefore, the immediate environment of most of the centers does not allow the development of winter sports and makes them prevailingly climatic resorts with summer operation and with supporting and servicing functions for the centers located at higher altitude.

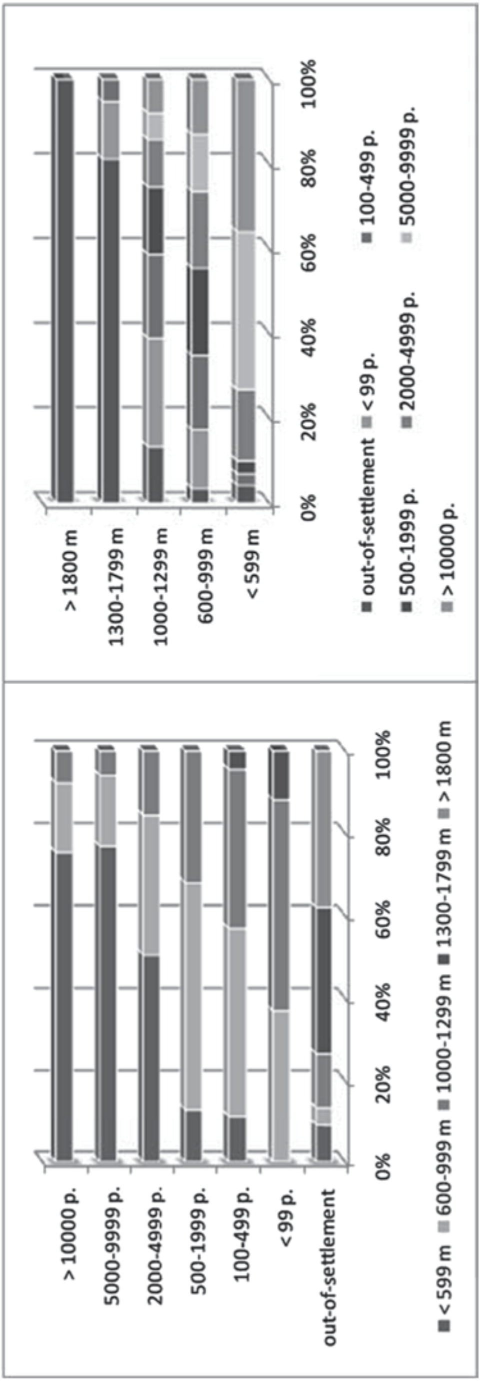

Fig. 24.1 Distribution of mountain tourist centers by altitude and population

Size The greatest share of mountain tourist centers represents out-of-settlement formations (40 %) without permanent population, followed by villages with population up to 499 people (28 %), but the share of very small villages with up to 99 inhabitants is considerable—12 %. The population group of 500–4999 inhabitants (24 %) comprises both villages and small towns, while the centers with more than 5000 inhabitants are entirely represented by towns (8 %), four of them with population greater than 20,000 people (Smolyan, Samokov, Velingrad, and Troyan). The out-of-settlement formations are represented by compact resort complexes, the biggest being Borovets and Pamporovo, or larger dispersed areas, incorporating several recreational spots or sites (Haidushki polyani, etc.). The distribution of mountain tourist centers by altitude and population is presented in Fig. 24.1. Other dimensions of the size (e.g., area) will be explored further.

Environment (Resources Utilized) Tourism resources in Bulgarian mountains predetermine the development of climatic treatment and prophylaxis, hiking, mountaineering, winter sports (alpine and cross country skiing, snowboarding, etc.). Besides, there are opportunities for spa and balneology, water-based recreation and water sports, hunting and fishing, cultural and ecotourism, rural tourism, gathering of wild fruits, mushrooms, herbs, etc. The main differentiation is based on the availability of winter sports infrastructure, thus the centers are classified as winter sport centers—50 in total (25 %) and other centers—149 (75 %). The identified winter sport centers are at different altitude and vary in size and accommodation capacity. Only two of them are towns (Bansko and Chepelare) and another six are villages, the rest being out-of-settlement formations (84 %). In most cases the development of ski facilities was related to existing mountain chalets. Their height distribution is as follows: from 600–999 m—4 %, from 1000 to 1299 m—26 %, from 1300 to 1799 m—56 %, and above 1800 m—14 %. It can be defined as inappropriate, based on the comparatively high share of centers lower than 1300 m, where the conditions for winter sports are modest, especially in the context of climate change and insufficient snow cover. The general picture of ski sports infrastructure is outlined by the following facilities in operation: nearly 290 km ski runs, 127 ski drags, 24 chair lifts and 3 cabin lifts. It should be pointed out that projects for the construction of new centers or enlargement of existing winter centers are developed in the last 10 years, currently in stand by position, envisaging about 600 km additional ski runs with the adjacent infrastructure.

The further research on the group of centers classified as "other" is expected to provide the ground for their more detailed subdivision based on currently utilized resources and types of tourism developed, most probably spa and balneology, cultural, eco- and rural tourism, etc.

Spatial Structure The criterion reflects the territorial and urban set-up aspect (common aspects of planning, construction etc.). The spa and balneology centers in the mountains are generally endotropic—the resort function is directly related to their central parts, which largely explains the role of spas as settlement forming factor. Falling in the same group are the centers with cultural heritage and rural tourism development. In the other mountain centers the tendency is to localize the tourism functions in the periphery or outside the resort settlements, including also the establishment of fully independent mono-functional centers with no permanent population (exotropic centers). The exotropic centers show both spot and areal development. The concrete classification based on the commented criterion will follow the defining of dominant type(s) of tourism of centers.

Capacity of Tourism Facilities (Number of Beds) Most of the mountain tourist centers have less than 1000 beds. There are a few large winter resorts (both settlements and resort complexes) with developed infrastructure which are orientated mainly toward the international tourism market (Borovets, Pamporovo, Bansko, Chepelare), but the majority of the centers serve mainly the internal market and social resort medication.

Level of Tourism Development and Market Significance Resorts are officially categorized into two groups: of national and of local importance, but this classification only reflects the quality of the resources and the resort potential, not the level of development. The level of development and market significance will be evaluated in regard of the tourist function once the full data about the centers is collected and processed.

Type of Privatization Privatization in mountain tourist centers started relatively late—in the mid 90s. In three consecutive mass privatization auctions, there were deals for shares of Pamporovo and for the whole packages of offered shares of Borosport, Sokolets-Borovets, and Rila-Borovets. The majority of the hotels in resort complexes have been sold out in the period 1999–2001 as independent parts of the joint-stock companies either cash or in combination with vouchers, including the possibility of worker–manager buy out of hotels. The numerous investment projects after 2000, for new facilities construction, are entirely private.

Property Structure As for the accommodation facilities and tourism infrastructure (e.g., ski zones' facilities), the property nowadays is 100 % private with the exception of a small number of state-owned medical treatment facilities, managed by the National Insurance Institute. The individual enterprises in the resorts are sold with a granted construction right, but without property rights on land. The land in the mountain resort complexes is part of the State Forestry Fund and is not included in the assets of the corresponding enterprises. The infrastructure of Pamporovo is included in the assets and is maintained by the Pamporovo joint-stock company. The biggest variety of land property is found in Borovets, where the underground and on-ground technical and engineering infrastructure is owned by the municipality. The privatization contracts include obligations of the new owners regarding participation in the maintenance and development of the infrastructure and the activities of common benefit. A significant result of the privatization is the fragmentation of accommodation facilities of resort complexes and their disintegration in terms of general management and marketing, accompanied by a concentration of ownership and almost complete monopolistic structure of the ski zones infrastructure of Bansko, Vitosha, Borovets, and Pamporovo, currently controlled by one and the same owner.

Origin of Investment In contrast to coastal tourism, significant investment is required to provide the necessary winter tourism or spa facilities in mountain tourist centers and resort complexes. In addition the difficult access and the sparse population in many mountain areas imply the outside participation and explain the exogenous character of the investments and overall involvement. In the socialist period, the funding is provided by the state, but after the changes in 1989 the investors are both national and international. The international companies involved show usually offshore registration but most probably their capital is national. Initially in the villages and small towns the investments are endogenous but recently the interest of outside investors is also growing.

Distribution of Costs and Benefits of Development This criterion is closely related to the origin of investment. Further investigation is needed to assess the current situation in quantitative and qualitative terms.

Management and Marketing Besides offering solutions to the problems of planning and preservation of the resort resources, the current legislation does not regulate, in any specific way, the management of the resorts and resort complexes. The increasing number of owners in the resorts aggravates the problems in their marketing activities as well. Similar is the case when facing the problems of attracting influential tour-operators, representation at international and national markets, active enterprise advertising, etc. The need for uniting the efforts and finances for the solution of these problems is becoming more and more obvious. The management models identified include: (1) Consortium (joint-stock company) through money or/and nonfinancial shares. The nonfinancial shares may include property rights and/or rights for use of common property and infrastructure (e.g., Bansko–Yulen, Chepelare); (2) Management through Tourist board or association, e.g., Samokov Tourism Council for Borovets (not working effectively) and the association “Pamporovo XXI century” in Pamporovo, uniting almost all owners of hotel and other facilities in the resort; (3) General administrating of a resort and/or resort complex by the municipality—in the rest of the cases.

Origin of Employees The criterion is very closely associated with the origin of investment and can be either internal or external. Further secondary and primary information needs to be collected to allow the classifying of mountain tourist centers.

Local Community Involvement In most of the municipalities with mountain tourist centers, tourism has gradually developed into a priority of development or is currently one of the main activities together with forestry, animal breeding, construction, etc. The leading role of tourism as economic sector is clearly revealed in the municipal development plans and the tourism development strategies in power at regional and municipal level. The great number of projects implemented at different territorial levels related to mountain tourism product development and its promotion is also an argument for the increasing community involvement in tourism development.

24.5 Discussion

The overview of the historical development and the defined structure of mountain tourist centers at the initial phase of the research demonstrate that tourism in mountain territories developed in a variety of ways, depending on the context of development, economic and social system, type of tourism, demand, and agents of development involved. On that basis, the following hypothesis of patterns is outlined bearing in mind that each of them shows a number of variations.

1. Development of out-of-settlement formations or mono-functional development—all of the centers in this group have developed in natural environment, outside of settlements with tourism being their main function—both for summer and winter holidays.

    - Spontaneous development with two variations:

        - Spot development—usually at higher altitude, represented by single or small group of establishments of single ownership (chalets of the Bulgarian tourist union), in the vicinity of which small ski centers developed (Rila lakes, Malyovitsa, Kom, Chumerna, etc.), but they are used also for hiking and recreation.
        - Extensive dispersed development—very often catalytic in type, they are usually larger in territory and their development started often without planning, in beautiful locations and utilizing attractive natural resources, mainly oriented toward domestic demand with the dominance of former institutional and enterprises' rest homes, youth camps, etc., privatized in the 90s and converted into hotel establishments with market operation, some of them are with infrastructure for winter sports (Panichishte, Batak, Uzana, Predela, etc.). The centers are popular both for winter and summer recreation. Some of them have been transformed into settlements (Panagyurski kolonii, Yundola, Panichishte).

    - Integrated development—planned resort complexes; the state is the main agent of development in a centralized system of construction, planning, and management of large-scale resort complexes of international importance for ski vacations (Borovets and Pamporovo); with the privatization, fragmentation of property occurs and they are further developed by private companies operating at national or local level thus currently their features include—interdependent facilities and owners, common infrastructure, single owner or concessioner of the ski zone, lack of clear mechanisms for common management and marketing. It should be considered that all the new projects for winter sport resorts fall in the specified groups as there is a single promoter or company behind them and they are planned outside of settlements.

2. Development of existing mountain settlements

   - Diffuse development of villages and small towns with two variations:

     – With change of property ownership—second homes acquisition and entrepreneurship, immigration of people from outside, change of residents' structure and lifestyle, social conflicts, change of demand (Kovachevitsa, Orehovo, etc.)
     – Without change of property ownership—related to rural tourism and other alternative forms of tourism and characterized by smaller scale of facilities and more indigenous capital; tourism emerges locally and is not imposed from outside (guest houses and family-run hotels), tourists are easily assimilated into the community and tourism development is less socially disruptive (Mogilitsa, Smilyan, etc.)

   - Multifunctional center development—these are usually bigger towns with many agents of development, tourism is one of the urban functions. In the outskirts of some towns, big winter sport centers have been developed (Bansko, Chepelare), but the rest rely on other type of tourist resources—spa (Velingrad, Devin), cultural heritage and traditions (Troyan, Elena), summer recreation, etc.

During the research some political factors have been identified that may be regarded as limiting or supporting the development of mountain tourist centers and they can be summarized as follows:

- Lack of institutional basis for implementing coordinated tourism development.
- Limited tools of tourism and regional policy related to mountain tourist center development and lack of understanding, capacity, and appropriate legislation for integrated tourism planning and development.
- Lack of clear defining, declaring, statute, functions and management of resorts, resort complexes, and other out-of-settlement formations.
- Spatial planning problems of resorts related to their obscure boundaries and land ownership.

Apart from these problems, emerging conflicts are defined especially in regards to the lack of balance between development and nature protection (e.g., Panichishte, Rila lakes, Vitosha), between the capacity for accommodation and the ski zones, in the case of which Bansko is the most vivid example. Furthermore, locals and environmentalists often defend extreme opposing views on existing conflicts between development and conservation, between national and local interests, and the decisions about mountain tourist centers' development are often taken under "street" pressure or are deliberately postponed in time.

Conclusion

Research of mountain tourism and its spatial structure in Bulgaria has been carried out mainly at higher territorial level (municipality) leading to a blurred picture and hiding the specifics of individual tourist centers. Defining mountain tourist centers is a real challenge, at least in two aspects: defining mountain areas and defining tourist centers themselves. Many sources have been used to compile the list of 199 mountain tourist centers with no pretention that it is exhaustive. The lack of actual systemized and correct information does not permit, at the initial phase of the research, to identify all the details of their structure, especially the economic and sociocultural one. For that reasons only a hypothesis about the patterns of development is presented, to be confirmed or modified once all the missing information and data is collected and analyzed. It will allow the patterns to be thoroughly described, including the stages of their development.

Nevertheless, on the basis of the identified patterns, problems, and conflicts some recommendations about the future development of mountain tourist centers in the country can be made. These include:

- Expanding the list of resorts and clear defining of their type, statute, functions and management.
- Maximum utilization of existing establishments and infrastructure instead of further extensive and quantitative development.
- Regional approach to tourism infrastructure development in search of synergies of development and economy of scale.
- Integrated tourism planning to mitigate and channel the existing conflicts between tourism development and nature conservation at local and regional level, taking into account local and regional interests in national tourism policy.
- Establishment of appropriate management models for mountain tourist centers, considering the above mentioned diversity of patterns of development based on their genesis, size, environment and tourist resources, capacity and level of tourist development, and, respectively, structure of ownership and other factors.

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Chapter 25
Net Primary Production in Forest Ecosystem of Middle Siberia: Assessment Using a Model of Tree Component Phytomass Distribution

Yulia Ivanova and Vlad Soukhovolsky

25.1 Introduction

Net primary production (NPP) is one of the key parameters characterizing processes that occur in forest stands. NPP is an integrated parameter characterizing the efficiency of absorption of solar energy by a plant community due to photosynthesis over a definite time period (e.g., a month or a year) over a definite area (Chapin et al. 2002). Based on NPP evaluations, one can predict the growth dynamics of tree stands and make long-term estimates of standing timber stock depending on the conditions of forest growth. The most commonly used methods of evaluation of forest stand NPP are:

- Evaluation based on in situ data on increase, fall, and loss of phytomass of tree stand components.
- Evaluation based on standing timber stock.
- Evaluation based on the data of satellite measurements of woodland reflectance spectra, with the signal calibrated using ground-based measurements of NPP.

However, difficulties associated with direct measurements of the phytomasses of tree components (the root component, in particular) and inaccuracies related to evaluations of conversion coefficients, which are used to convert timber stock into phytomass, complicate calculations of primary production. NPP values obtained using these approaches may vary significantly, even for the same area.

One of the most common approaches to the evaluation of forest ecosystem NPP is based on phytomass increase, leaf fall, and loss of phytomass in the tree stand

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over a definite period of time. The simplest equation of the dynamics of tree stand phytomass production can be written as follows:

$$M(T+\Delta T) = M(T) + NPP(\Delta T) - R(\Delta T) \quad (25.1)$$

where, $M(T)$ and $M(T+\Delta T)$ are phytomasses of tree stands aged T and $T+\Delta T$; $R(\Delta T)$ is phytomass loss for all tree components in the community for the time period ΔT.

From (25.1), we obtain the NPP value (ΔT):

$$NPP(\Delta T) = M(T+\Delta T) - M(T) + R(\Delta T) \quad (25.2)$$

However, although Eq. (25.2) seems conceptually simple, ground-based measurements cannot provide accurate evaluations of the NPP of tree communities. Forest inventory measurements can be conveniently used to evaluate the increase in the amount of phytomass of the stem wood within the age range from T to $T+\Delta T$, but the accuracy of evaluation of the increase in branch and leaf phytomass is lower (Clark et al. 2001; Kloeppel et al. 2007). The main reasons why it is difficult to evaluate NPP from Eq. (25.2) are that, first, direct measurements of the phytomass and an increase in the phytomass of the tree root system are nearly impossible and, second, it is hard to evaluate phytomass loss $R(\Delta)$ as the data on the death rates of some roots, branches, and bark are very inexact (Sala et al. 1988; Waring et al. 1998; Chen et al. 2004). Thus, NPP evaluations based on forest inventory data may vary widely.

In many cases, the data on the phytomass of tree components and changes in the phytomass are lacking, and the only available data are inventories of the standing timber or measurements of the height and diameter of the trees in the stand. Then, calculations of the componential structure of the tree layer phytomass (the phytomass of the stems together with the bark, roots, branches, and leaves) and NPP evaluations are performed using regression equations that characterize relationships between the phytomasses of tree components and the standing timber stock or tree diameters and heights (Alexeyev and Birdsey 1994; Usoltsev 2001, 2010; Kolchugina and Vinson 1993; Shvidenko et al. 2007).

This study addresses the problem of developing methods for NPP evaluation based on ground-based measurements that would be more accurate and reliable than those currently used and could be employed to calibrate remote sensing data.

25.1.1 Material and Methods

Literature data on phytomasses of tree components and standing timber stocks in tree stands in Middle Siberia (the Yenisei River basin) situated between 89 and 130°E and stretching over 1600 km from the forest tundra zone (66°N) to the Sayan Mountains (about 51°N), were used to evaluate the NPP of tree stands. This area includes northern, Middle Siberian, and southern forests, forest steppe, and mountain forests. Taiga forests of this region consist of rather few tree species: several larch

(*Larix sibirica*, *L. kajander*, *L. gmelini, L. czekanovski)* and pine (*Pinus sibirica*, *Pinus sylvestris* L.) species, fir *Abies sibirica*, birch *Betula pendula,* and poplar *Populus laurifolia* (Krasikov 1987; Usoltsev 2001; Usoltsev 2010; Nemich 1991; Matveeva et al. 2005; Pozdnyakov 1975a, 1975b). Most of the studies analyzed in this chapter report the data on the phytomass of aboveground tree components—stems with the bark, branches, and leaves (needles)—in single-species forest stands of different ages.

25.1.2 Method of NPP Calculation

To evaluate the NPP of a tree stand, one needs to know how the tree phytomass has changed over a certain period of time. These changes are determined using standard measurements of tree or tree stand components. Depending on the amount of the available data, we propose three approaches to NPP calculations using ground-based measurements. It is very difficult to obtain the data on the phytomass of all above ground and below ground tree (tree stand) components and, thus, this is a very rare case.

In this case, the phytomass $TNPP\ (T,\ T+\varDelta T)$ produced in the stand over the age interval ($T,\ T+\varDelta T$) is calculated using the following expression:

$$TNPP(T, T+\Delta T) = MQ(T+\Delta T) - MQ(T) + \frac{\Delta T}{2\theta}[ML(T) + ML(T+\Delta T)] \quad (25.3)$$

where $\varDelta T$ is the age interval between two adjacent measurements of phytomass dynamics, ML is phytomass of leaves or needles, MS is phytomass of the stem with the bark, MR is root phytomass, MB is branch phytomass, $MQ(T) = MS(T) + MB(T) + MR(T)$; θ is characteristic lifespan of leaves or needles.

Equation (25.3) takes into account changes in the phytomasses of the stem, roots, and branches and the leaf fall for the time $\varDelta T$ between two closest inventories of the stand phytomass. The yearly leaf fall is estimated as the average phytomass of leaves (needles) of ages T and $T+\varDelta T$, taking into account the characteristic lifespan θ of the leaves (needles) of the tree species studied. For broadleaved trees and larch $\theta=1$; for other conifers—from 4 to 8 years (Kramer and Kozlovsky 1983).

Using (25.3), one can find the average NPP value for the forest stand within the age interval from T to $T+\varDelta T$:

$$NPP(T,\ \Delta T) = \frac{TNPP(T, T+\Delta T)}{\Delta T} \quad (25.4)$$

As the loss of the bark, roots, and branches is not taken into account in (25.3) and (25.4), expressions (25.3) and (25.4) give the lower bound estimate of NPP.

The most frequent case is when the data on measurements of tree stand aboveground phytomass are available, and they are used to evaluate the aboveground NPP only. Then, the phytomass of the root system is not taken into account. The authors propose an approach that enables calculation of the root system phytomass analytically, using a mathematical model, and, thus, obtain the total NPP value of the tree stand.

If the data only provide phytomasses of the aboveground tree components, but the phytomass of the roots remains unknown, NPP evaluation using Eqs. (25.3) and (25.4) is impossible. In this study, to obtain the lacking data on the root phytomass, we use the theoretical model of the resource distribution among tree components (stems together with the bark, roots, branches, leaves (needles)).This model treats the tree (or a forest stand) as a system consisting of *n* components—components—among which the inflow of energy resource is distributed. The model assumes that the tree or the stand distributes the inflow of energy resources so that the maximum viability is attained under limited resource conditions. The optimal distribution of the phytomass between the components of the tree of age *T* is described by the Zipf–Pareto equation (Isaev et al. 2007; Sukhovolsky 1997):

$$M(i,T) = M(1,T)\cdot i^{-b(T)} \tag{25.5}$$

Where, *i* is the rank of the component (i.e., its number in the row that starts with the rank 1 part, which has concentrated the greatest amount of the resource); *M (i, T)* is the phytomass of the i^{th} component; *b(T)* is the parameter characterizing the proportions of the phytomasses of age *T* tree components. At $b(T) \to 0$, the phytomass is uniformly distributed among tree components, while at large *b(T)* values, the phytomass is concentrated in the rank one component (usually stem wood).

If we take the logarithm of (25.6), we obtain a linearized equation

$$\ln M(i,T) = a(T) - b(T)\ln i \tag{25.6}$$

Where, $a(T) = \ln\ M(1,T)$ is a logarithm of the phytomass of the rank one component.

Thus, in the log–log coordinates, the rank distribution of tree component phytomasses in the Zipf–Pareto model lies on a straight line.

Figure 25.1 shows a typical form of the function of the rank distribution of tree componentphy to masses in the stand in the log–log coordinates, when phytomasses of all components are known. Figure 25.1 suggests that when phytomasses of all tree components in the stand have been measured, the phytomass distribution among tree components is successfully described by Eq. (25.6).

In Fig. 25.1, the greatest value of rank 1 phytomass corresponds to the stem phytomass, phytomass of the root system corresponds to rank 2, followed by logarithms of branch and needle phytomasses in descending order. In these examples either the values of the logarithm of root phytomass nearly lie on the theoretical curve (*P. sylvestris* L.) or the value of the logarithm of root phytomass is below the level predicted by the model (*A. sibirica*). The reason for this must be that not all roots were extracted and measured.

If only the phytomasses of the aboveground components are known, the root phytomass can be calculated assuming that the distribution of the phytomasses is described by Eq. (25.6). As an example (Fig. 25.2), we give the sequence of

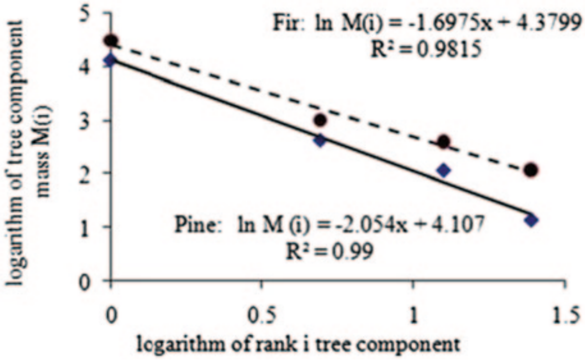

Fig. 25.1 Rank distribution of the phytomasses of tree components in the stand when the phytomasses of all components are known. *Solid line* the line of the trend for the rank distribution of phytomass among components for *Abies sibirica* aged 96 years (Usoltsev 2010); *dashed line* the line of the trend for the rank distribution of phytomass among components for *Pinus sylvestris* L. aged 100 years. (Pozdnyakov 1975a)

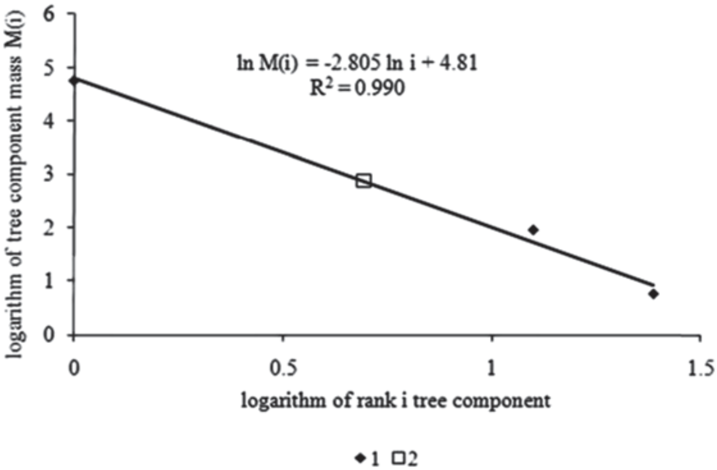

Fig. 25.2 Rank distribution of the phytomasses of tree components in the stand when only phytomasses of the aboveground components are known, the root rank is assumed to be equal to 2 (*1* field data; *2* calculated root phytomass)

calculations of tree root phytomass in the larch *L. kajander* stand aged 130 years (Pozdnyakov 1975a). For this stand there are three known values of aboveground tree phytomasses: the phytomass of the stem (with the bark)—116.7 t ha^{-1}; the phytomass of the branches—7 t ha^{-1}; and the phytomass of the needles—2.1 t ha^{-1}. For all possible ranks of the roots (from 1 to 4), we calculated parameters of the Eq. (25.6) of the rank distribution of phytomasses among aboveground components for different hypotheses of the root phytomass rank (Table 25.1).

Table 25.1 Parameters of the linearized Eq. (25.6) of the rank distribution of phytomasses for all possible root ranks

Possible root rank	Parameters of regression equation (6)			Evaluation of *MR* (t ha^{-1})
	a	*b*	R^2	
1	8.70	5.87	0.983	6002.9
2	4.81	2.80	0.990	17.6
3	4.49	2.90	0.949	3.7
4	4.69	3.70	0.994	0.6

Then, of the possible root ranks given in Table 25.1, we select the rank for which the calculation yields an acceptable value of *MR*, with coefficient of determination R^2 having the maximum value. Table 25.1 shows that for ranks 1 and 4, *MR* values are ecologically incorrect. The evaluation of the tree root phytomass at 6000 t ha^{-1} is absurdly high—if that were the case, with the stand density 1000 trees ha^{-1}, which is usual in Siberia, the phytomass of the roots of one tree would reach about 60 t. On the other hand, the tree root phytomass in the stand evaluated at 600 kg ha^{-1} is meaninglessly small, resulting in the root phytomass of one tree below 1 kg. This phytomass would not allow the roots to keep those trees vertical whose aboveground phytomass reaches 125.8 t ha^{-1}. Thus, the hypotheses of the root ranks equaling 1 and 4 should be discarded. The coefficient of determination R^2 for the hypothesis of the root rank equaling 2 is greater than the value of R^2 for the hypothesis of the root rank equaling 3. Therefore, the root phytomass was taken to be 17.7 t ha^{-1}. Figure 25.2 shows the rank distribution of tree phytomasses for the case of the root rank being equal to 2.

Having calculated the root phytomass, one can use the data for all components of the forest stand phytomass to evaluate the NPP using Eqs. (25.3) and (25.4).

The data on the standing timber stock traditionally do not include the data on the phytomass of branches, leaves (needles), and roots. The reason for this is that the economic value of the tree stand is directly related to the timber volume, which is determined by measuring tree stems. The methods currently used to convert timber stock to phytomass using conversion coefficients or allometry formulas often give different NPP values(Shvidenko et al. 2007; Zamolodchikov and Utkin 2000). The authors of this study propose an elegant method of NPP calculation from the data on the standing timber stock, using the model of tree phytomass distribution among tree components described above.

If for ages *T* and *T+DT* the only known values are standing timber stocks *V(T)* and *V(T+DT)* in the stands, a modified method of NPP calculation can be proposed, if the form of function *b(T)* from Eq. (25.6) is also known. Then NPP calculation for the age interval *T* and *T+DT* is done as follows:

- Phytomasses *MS(T)* and *MS(T+DT)* of the standing timber of the ages *T* and *T+DT* are calculated from standing timber stocks *V(T)* and *V(T+DT)*, using formula $MS(T) = \rho V(T)$, where *r* is wood density. For tree species of boreal forests the values of wood density vary from 400 kgm^{-3} for the fir to 690 kgm^{-3} for the larch (http://www.sci.aha.ru).

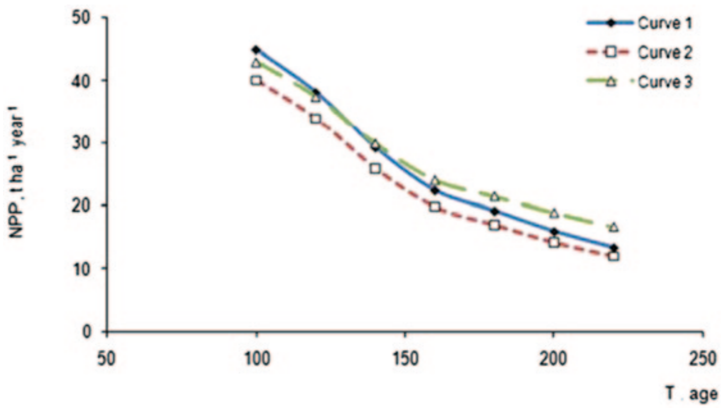

Fig. 25.3 NPP(T) evaluations based on the data on the phytomasses of all tree components (Curve 1), data on the timber stock (Curve 2), and the data on phytomasses of only aboveground components (Curve 3).

- Using the known values of*b(T)* and *b(T+DT)* and the calculated values of phytomasses *MS(T)* and *MS(T+DT)*, phytomasses of roots, branches, and leaves (needles) in the age groups*T* and *T+DT* are calculated using Eq. (25.6). In order to describe function *b(T)*, the following equation was introduced:

$$b(T) = b_m \frac{T}{T_{1/2} + T} \tag{25.7}$$

where b_m is the maximum value of *b(T)*; $T_{1/2}$ is the age of the tree stand at which $b(T)=b_m/2$;

- Using Eqs. (25.3) and (25.4), NPP age dynamics is calculated.

Are there significant differences between *NPP* evaluations based on different datasets obtained in the field? Figure 25.3 shows NPP(T) curves for the same *P. sibirica* stand obtained by using the data on the phytomasses of all tree components, the data on phytomasses of only aboveground components, and the data on the timber stock alone, respectively (Usoltsev 2001). NPP evaluations based on the data on the timber stock in mature tree stands, where $b(T)=b_{max}$, were done using the value $b_{max}=2.22$.

Figure 25.3 clearly shows that NPP(T) evaluations based on the data on the phytomasses of all tree components and data on the phytomasses of only aboveground components, with the root phytomass calculated using Eq. (25.6), are similar for all ages. Thus, the proposed method of NPP calculation based on the data on the timber stock alone gives quite reliable evaluations of NPP.

Conclusion

The authors' method of NPP evaluations based on the model of tree phytomass distribution among components has a number of advantages. It makes unnecessary the hard labor of extracting the root mass from the ground. The value of root phytomass is calculated using the model if the data on the aboveground phytomass of the tree (tree stand) are available. We have applied this model to calculate the root phytomass for more than a thousand direct field measurements using datasets on the distribution of the phytomass among tree components (Usoltsev 2010; Usoltsev 2001; Shevelev and Subochev 1983; Krasikov 1987; Falaleev 1985; Pozdnyakov 1975a, b; Protopopov 1971; Nemich 1991; Pleshikov et al. 2002; Matveeva et al. 2005; Pryazhnikov and Pertsev 1971; Shakhnovich 1984; Orlovsky et al. 1974; Kulagina 1978) and 97 % of the examples give the coefficient of determination, R^2 higher than $R^2 = 0.98$(least-squares method).Using the model proposed in this study, one can calculate NPP values from different datasets, which may contain information on the phytomass of different tree stand components or forest inventory information on timber stock alone.

It is noteworthy to mention that the widely used regression approach for evaluation of primary production is not based on any serious theoretical concept of tree growth processes, while the models used in this study are based on theoretical ideas of the optimality of plant growth processes. The approaches proposed in this study can reduce the amount of the preliminary data necessary to calculate primary production and enhance the accuracy of NPP calculations.

Acknowledgement The study was supported by RFBR Grants Nos. 12-05-00494.

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Chapter 26
The Influence of Altitudinal Zonality on Spectral Characteristics (MODIS/Terra) Mountain Forests of Western Sayan

Nikolay Kukoba, Yulia Ivanova and Irina Botvich

26.1 Introduction

Assimilation of carbon by green plants is one of the most important processes that provide qualitative and quantitative estimates of the events occurring in the biosphere (Running et al. 1999). Carbon assimilated by plants is used by them to increase their biomass and lies at the foundation of food chains on Earth. Net primary production (NPP) is a measure of carbon assimilation by plants, determining the amount of net carbon sequestration by plants. NPP is highly variable in time and space. It is affected by such factors as climate, vegetation distribution, and land management at both a local and global scale (Goetz et al. 1999; Cao et al. 2004).

The purpose of this study was to investigate the influence of altitude on spectral characteristics of the forests of the West Sayan Mountains based on satellite (MODIS/Terra) data. The effects of the altitudinal zonation and geographical and environmental properties of the study area on vegetation indices and NPP values were studied for the time period from 2000 to 2012.

Moderate-resolution Imaging Spectroradiometer (MODIS) data products MOD09, MOD11, MOD13, MOD15, and MOD17 were used in this study (http://modis-land.gsfc.nasa.gov/npp.html). Vegetation indices, humidity index, temperature, and NPP values were obtained using conventional methods. Vegetation indices, including Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), and Enhanced Vegetation Index (EVI) and NPP values (http://gis-lab.info/qa/modislandprod.html) were used in this study. The study area was the West Sayan Mountains. The vegetation of this area shows distinct altitudinal zonation, i.e., the species composition and structure of mountain forests are different at

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different altitudes. Qualitative and quantitative characteristics of mountain forests are determined by soil temperature, air temperature, and other altitude-dependent natural factors.

26.2 Material and Methods

The West Sayan Mountains are a mountain system in South Siberia, stretching for 650 km. The vegetation of the West Sayan Mountains shows vertical zonation, consisting of the steppe, forest steppe, subtaiga, black taiga, taiga, subalpine, and alpine zones. The two last mentioned zones are represented by high-altitude vegetation. The West Sayan Mountains are dominated by the dark-coniferous taiga species such as Siberian pine, fir, and spruce. At higher altitudes, the trees are smaller and Siberian pine becomes a dominant species (Krasnoborov 1976). The size of the study plot was 10 × 10 km (center: lat. 52, 984409; lon. 93, 136241). The difference in elevation in this area is 650–1450 m. It contains three altitudinal zones, which differ in their altitude, plant growing season, and type of vegetation (Table 26.1).

The data analyzed in this study were retrieved from the MODIS/Terra database. The MODIS data archive contains the data for more than 10 years. Its aim is to collect the data for calibrated global interactive models of Earth as a whole system. MODIS data for Earth's entire surface are provided by the Terra satellite every other day in 36 spectral bands (within the 0.405–14.385 μm range), at a 250–1000 m resolution, enabling global and regional modeling. The MODIS–NPP data are open-access data and are widely used in atmosphere, ocean, and land studies.

In this study we used the MOD17—NPP product from the MODIS/Terra satellite, which contains the data on global NPP, and the MOD09, MOD11, MOD13, and MOD15 products. Space images were obtained from the www.lpdaac.usgs.gov site, which contains a free archive center of NASA land processes, and Hierarchical Data Format File (HDF) files for the time period from 2000 to 2012 were obtained from the File Transfer Protocol (FTP) server ftp://e4ftl01.cr.usgs.gov/. The data on the spectral characteristics of the underlying surface are given as 8-day composite data in the *hdr file format, at 500 m spatial resolution (vegetation indices) and 1 km spatial resolution (NPP evaluations). The original data were geometrically corrected. The ENVI 4.7 + IDL software was used to process satellite data and obtain the target values from the remote sensing data.

Table 26.1 Altitudinal forest zones in the West Sayan

Altitudinal zones, true altitudes (m)	Growing period (days)	Plants
Black, fir-Siberian pine zone, 350–900 m	145–155	Siberian pine, fir, birch stands
Mountain taiga, 800–1400 m	145–120	Fir stands (more seldom—Siberian pine stands)
Subalpine zone, 1300 m and higher	120–100	Fir-Siberian pine open woodland

An Interactive Data Language (IDL) program for integrated processing of satellite data was developed in order to optimize data retrieval. This software consists of a number of modules intended to obtain the target values of NDVI, LAI, EVI, and NPP. The program automatically calculates the data for the selected end product and calibrates them by converting the bit value of the raster into the target index; then the result obtained is recorded in the *TXT file created by the program.

26.3 Results and Discussion

Mountain forest ecosystems situated in different altitudinal zones differ in vegetation composition, duration of the plant growing season, and, hence, NPP values. In order to be able to monitor the quality and state of the vegetation cover and detect changes related to altitudinal zonation, one should know how these changes are reflected in spectral characteristics of the mountainous area. In most cases, annual changes in the boundaries of altitudinal zones, forest stands in particular, are very slight. The boundaries of mountain forests consisting of certain species may be changed rapidly, due to human impact or natural disasters (cuttings, fires, windthrow), or gradually, due to climate change, environmental pollution, etc.

Figure 26.1 shows 8-day composite values of NPP for three altitudinal zones. One can clearly see the NPP values for the subalpine zone, which remain the lowest throughout the growing season. The reasons for this are the shortest growing season and characteristic properties of this ecosystem, which contains rather few trees but is dominated by herbaceous vegetation.

NPP values for the mountain taiga and black taiga zones determined using satellite data are practically indistinguishable from each other although according to ground-truth data the mountain forests growing in these zones are significantly different in their species composition and productivity. The black taiga forests contain

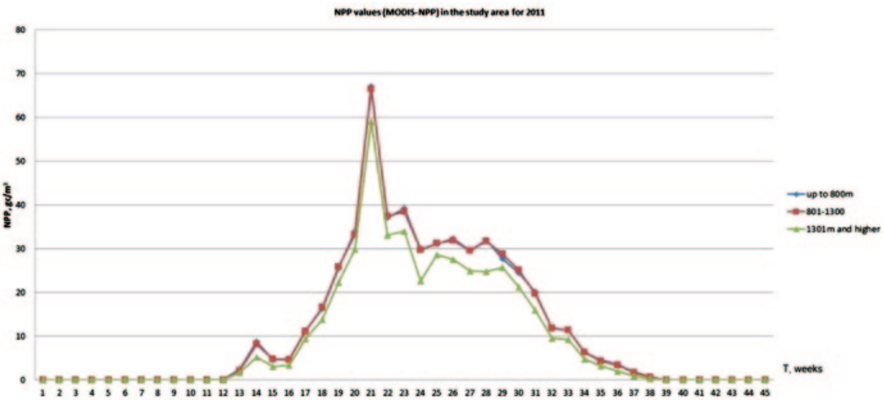

Fig. 26.1 NPP values (MODIS-NPP) in the study area for 2011

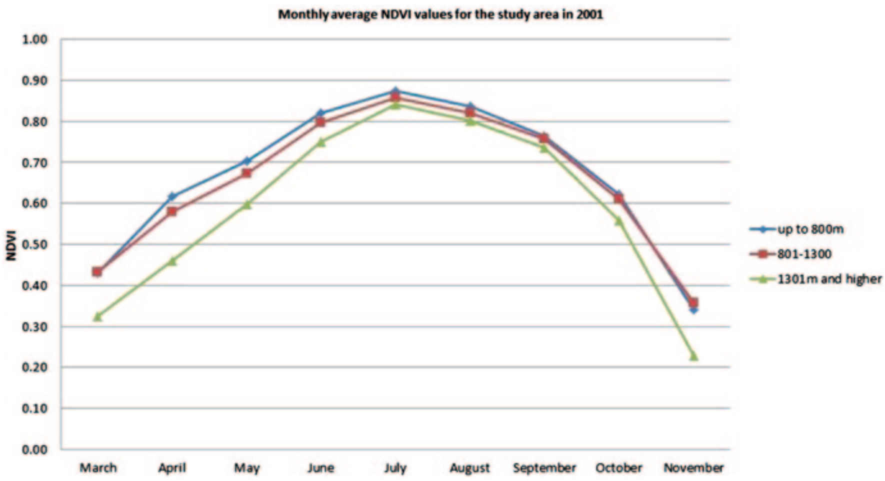

Fig. 26.2 Monthly average NDVI values for the study area in 2001

many broadleaved tree species, while the mountain taiga zone is dominated by conifers. Thus, based on the MODIS–NPP model alone, this area cannot be divided into altitudinal zones although different altitudinal zones have dissimilar productivities.

The widely used NDVI indicates vegetation density in a definite image point and is defined as the difference between red light reflectance and infrared light reflectance values divided by the sum of these values. The calculation of NDVI is based on two most stable (unaffected by other factors) portions of the spectral reflectance curve for vascular plants. The maximum of solar radiation absorption by the chlorophyll of higher vascular plants falls in the red-light region of the spectrum (0.6–0.7 µm), while the reflectance maximum of leaf cellular structures lies in the infrared region (0.7–1.0 µm). Using MODIS products, we obtained NDVI values, whose curves are shown in Fig. 26.2 (http://gis-lab.info/qa/ndvi.html).

The curves in Figs. 26.2 and 26.3 suggest that NDVI and EVI values change in different ways in the three altitudinal zones under study, but these differences are almost indistinguishable, especially in summer months. The differences in the behavior of EVI and NDVI curves are associated with the methods used to calculate these vegetation indices.

Thus, it is very difficult to differentiate between mountain forests growing in different altitudinal zones based on monthly averages of vegetation indices.

The qualitative and quantitative changes in the vegetation cover that can significantly influence vegetation indices occur in spring, at the beginning of the growing season, and in autumn, when the growing season finishes. Figures 26.4 and 26.5 show LAI values for 2001 at the beginning and end of the growing season, based on the 8-day composite data. The curves show that the values of the vegetation index are strongly dependent on altitudinal zonation, in spring months in particular.

The simplest way to divide the vegetation cover into altitudinal zones is based on recording the time of the first spring phenological events in the vegetation growing

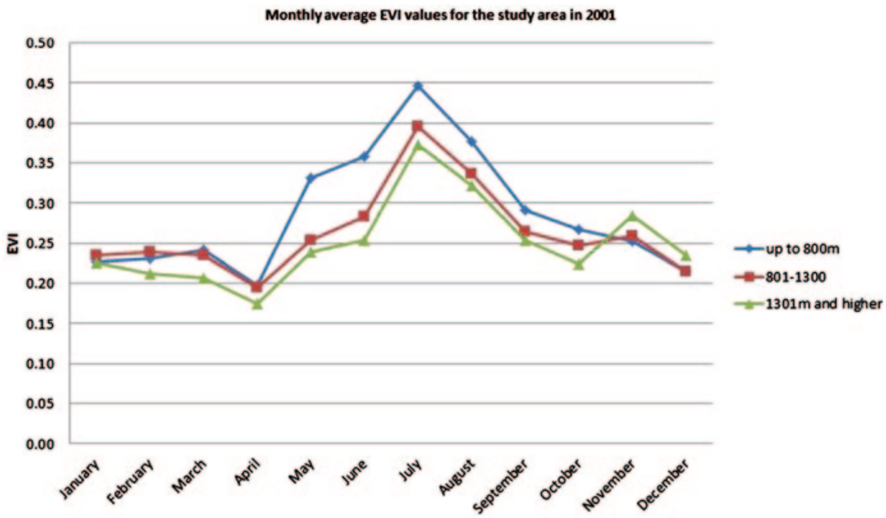

Fig. 26.3 Monthly average EVI values for the study area in 2001

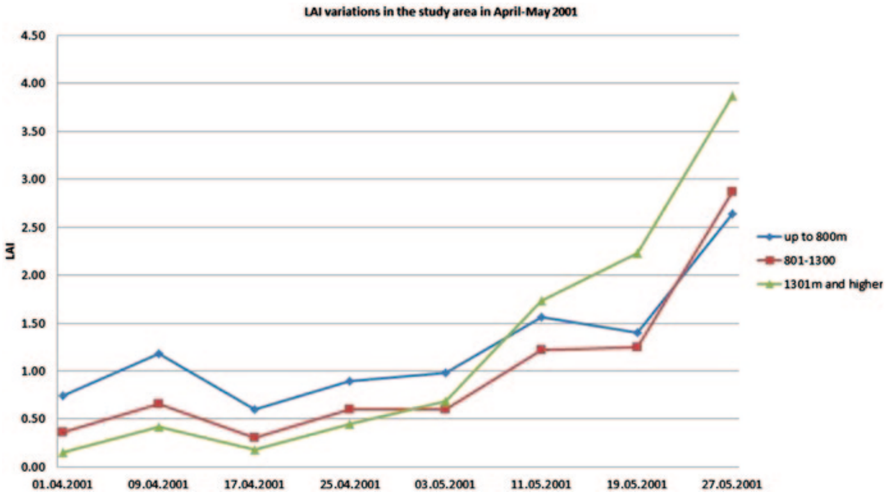

Fig. 26.4 LAI variations in the study area in April-May 2001

at different altitudes: the higher the altitude at which plants grow the later the spring events occur. In spring, at the beginning of the growing season, the green mass of the plants increases rapidly. Although monthly average values of vegetation indices for April and May are similar in different altitudinal zones, the start of the growing season in them occurs at different dates and with different intensities. Therefore, the use of a smaller time step in measuring spectral characteristics, e.g., 8-day composites, can provide vegetation indices that will differ significantly between altitudinal zones.

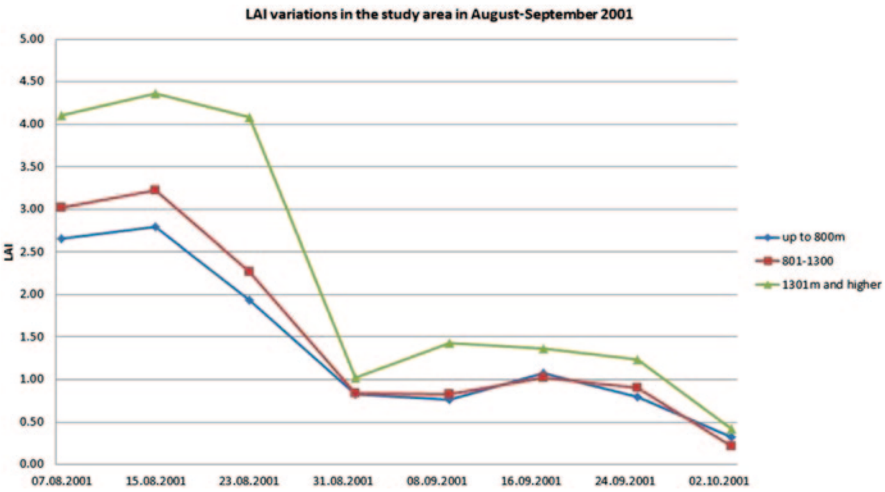

Fig. 26.5 LAI variations in the study area in August-September 2001

Conclusions

NPP values obtained using the MODIS–NPP model did not show any distinct differences between productivities of mountain forests growing in different altitudinal zones, and the NPP values for the black taiga and mountain taiga zones were practically similar. The MODIS–NPP model is a model intended to calculate global NPP values. It uses empirical data for 15 major biomes of the earth's vegetation, but it certainly cannot take into account regional factors such as distinct altitudinal zonation of the West Sayan Mountains. Thus, these NPP evaluations can only be used to analyze NPP changes in time, temporal trends in the NPP, etc.

Division of the mountain system area into altitudinal zones associated with definite types of vegetation should be based on the data on vegetation indices with temporal resolution of no more than 8 days, taken at the beginning of the growing season. These data can be used to conduct annual monitoring of the boundaries of altitudinal zones.

Acknowledgement The study was supported by RFBR Grants No 12-05-00494.

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http://gis-lab.info/qa/ndvi.html

Chapter 27
Subalpine Ecosystem and Possible Impact of Climate Change on Vegetation of Kaz Mountain (Mount Ida—NW Turkey)

Recep Efe, Süleyman Sönmez, Isa Curebal and Abdullah Soykan

27.1 Introduction

Mountain systems account for roughly 21 % of the terrestrial surface area of the globe and are found on all continents. Mountain ecosystems in the world are highly sensitive to climate change. Recent scientific studies led by the experts, scientists, and Intergovernmental Panel on Climate Change (IPCC) are that global climate change is happening and will present practical challenges to local ecosystems in mountains.

Analyses and estimates have shown that the magnitude of the climate change rises along with elevation. This condition is observed in temperature and as changes in precipitation patterns. There is a critical relationship between the climate change, biodiversity, and human activities. The ability of species living in the mountain ecosystems to adapt to new conditions and migrate is limited after a climate change. Therefore, mountainous regions resemble islands surrounded by other ecosystems (Busby-Spera 1988a).

The past climate changes have demonstrated that most of the plant species genetically migrate rather than adapt to these changes (Huntley 1991).

Mountain ecosystems have special climatic and biogeographical features. Mountains are an important source of water, energy, minerals, forest products, agricultural products, and biological diversity (O'Connor 1984; Aplada et al. 2007). Mountain and hillside areas hold a rich variety of ecological systems. Because of their vertical dimensions, mountains create gradients of temperature, precipitation, and insolation. The ecosystems on high-elevation regions and mountains are strongly affected by climate, which gets cooler as elevation increases. Due to orographic conditions, climatic zones and vegetation belts occur strikingly and vertically in high mountains (Grabherr 1994; Lugo et al. 1999). The subalpine layer is the level between the upper forest boundary and the alpine belt (Beniston 1994; Körner 2003). The

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features of flora and fauna in the mountains tend to depend on elevation, because of the change in climate. This dependence causes vegetation zones (Perry 1994; Price 1986). This belt lies between the elevations of 1600 and 2000 m in the western Anatolia. Temperature and precipitation conditions along this belt are different from those of the lower and middle parts of the mountain. The geology and soil formation conditions are the other factors playing a role in the formation of a special ecosystem (Cürebal et al. 2012; Efe et al. 2012).

Few studies were conducted in the area on vegetation, endemic species, endangered plants (Gemici et al. 1998; Ekim et al. 2000; Dirmenci et al. 2007; Efe 2010; Efe et al. 2012).

The subalpine level or zone is the belt between the upper forest boundary and alpine level (Gungor 2011). There are stocky and sparsely scattered trees and some deformed woody plants on this level. In the South Marmara Region, the upper forest boundary runs between the elevations of 1950 and 2000 (Çepel 1978; Sönmez and Boyraz 2003). It is accepted that the alpine level begins from the upper forest boundary at middle latitudes.

Temperate forests of lowlands and foothills are replaced with bush and perennial species on higher elevations in Kaz Mountains (Mt. Ida) in western Anatolia. Above 1600 m the ecosystem is dominated by grasses, herbaceous and low-growing shrubs (Karabacak et al. 2006; Öztürk et al. 2010; Uysal 2010; Öztürk et al. 2011). Many different plant species such as grasses, sedges, and cushion or polster plants live in the subalpine environment in Kaz Mountain. These plants adapted to the harsh conditions of the mountain environment, which include low temperatures, ultraviolet radiation, and a short growing season. Black pine and juniper are typical trees grow in montane forests. Weathered rocks produced soils developed enough to support grasses and sedges. In addition to acts of nature, the conditions of biodiversity are threatened by tourism, collection of medicinal plants. Kaz Mountains are experiencing environmental degradation such as many other mountains in the world.

27.2 Materials and Methods

The study area is the subalpine zone of Kaz Mountain in the northwestern Anatolia (Fig. 27.1). Research started with a literature review. 1/25.000 scaled toposheets were used to determine and examine the topographic and geomorphological features. 1/100.000 scaled digital geologic maps produced by M.T.A were used to understand the tectonic structure and lithological features. Information on soils of the area was obtained from the 1/100.000 scaled maps and from fieldwork studies.

On the basis of the data provided by the Edremit Meteorological Station, temperature and precipitation data were interpolated based on the elevation. It was intended to find out about the climate of the subalpine zone. The study area was visited in various seasons. Observations and research about the vegetation, geology, geomorphology, hydrography, and anthropogenic factors were carried out. Plant species were collected and Flora of Turkey and East Aegean Islands (Davis 1965–1985; Davis et al. 1988; Güner et al. 2000) was used for the identification of plant specimens.

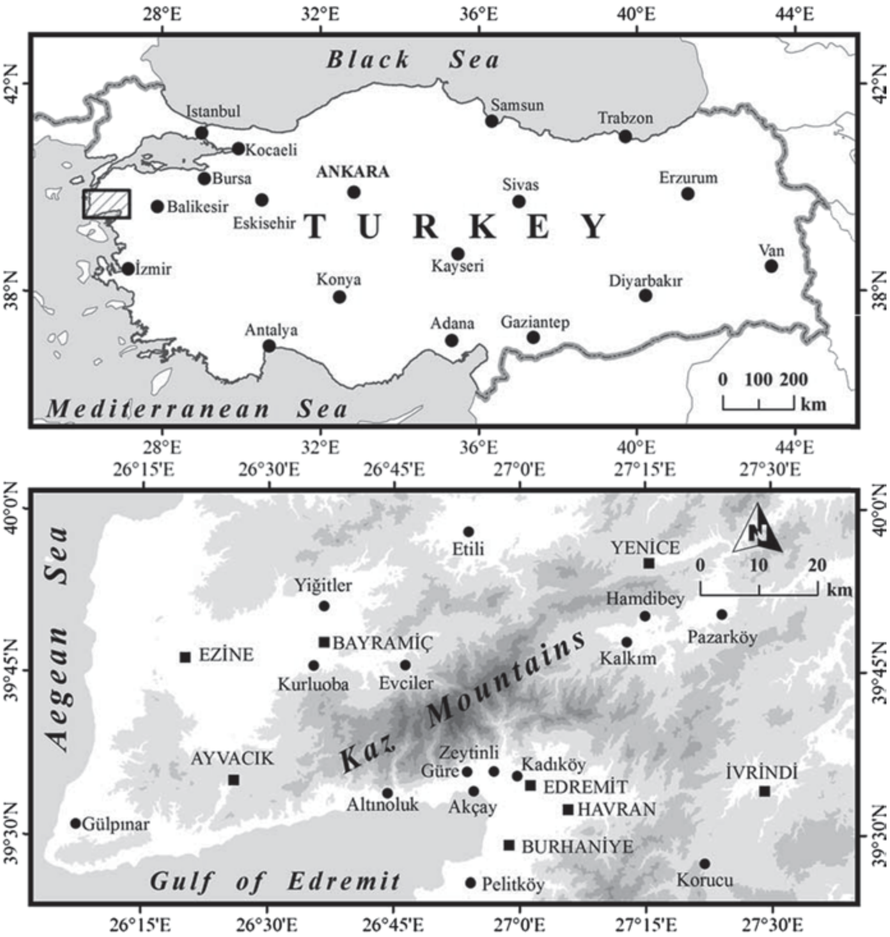

Fig. 27.1 Location of study area

The goal of the study is to find out the features of the vegetation of the subalpine zone and natural and anthropogenic factors based on all these data. Additionally, the subalpine vegetation of the area was compared with the vegetation belts of some high mountains such as Uludağ (Çepel 1978), Akdağ (Sönmez 2006), and Şaphane (Tel 2011).

27.3 Geographical Properties and Setting

Kaz Mountain (Mt. Ida) is located in northwestern Anatolia, on the coasts of the Gulf of Edremit. The mountain lies along the southwest-northeast direction, and its highest point has an elevation of 1774 m. The main summits are Babadağ hill (1765 m) in the west, the Kırklar hill (1710 m) in the north, Nanekırı hill (1646 m) in the east, Sarıkız hill (1726 m) in the south, and Karataş hill (1774 m). Kaz Mountains have a high mountain ecosystem in areas situated above 1600 m. The area where the subalpine zone features are observed is 25 km^2. The Kaz Mountains are composed of various igneous, metamorphic, and sedimentary rocks, but metamorphic rocks are more common.

The amount of annual precipitation exceeds 1000 mm and reaches the maximum level in the area and climatic drought disappears. Yet, lithological features lead to a ground drought.

Rocks like limestone and schist outcrop the subalpine zone of Kaz Mountains and constitute an important feature of this area. While limestone is exposed to chemical dissolution due to rain water, schist undergoes physical dissolution and produces stacks of stones and blocks. Soil is very thin on the higher parts (Cürebal and Erginal 2007). In some places, only the bedrock is present. Soil is either a little acidic or neutral.

Precipitation falls as rain and snow. Water flowing on the surface forms rivers and water infiltrates through diaclases feed ground water. There are some sources surfacing on contacts, slopes, and karstic areas. The subalpine zone of Kaz Mountain is rich in water (Soykan et al. 2008).

Natural forest, located above 1600 m on Kaz Mountains, was degraded because of natural and human effects. In this area, trees are short, and the vegetation is sparse. The winds are strong; soil is either not present or very thin. In addition, this area is a sacred place (Sarıkız) visited by Turkomans for centuries.

Black pines (*Pinus nigra*), Kazdağı fir (*Abies equi-trojani*) and polster plants make up the main elements of the vegetation of the subalpine zone, respectively, in the southern aspect, northern aspect, and treeless areas (Atalay and Efe 2010a, 2010b).

The area was exposed to human effects for at least 5000 years as it is located near the ancient Troy and Assos. This geomorphological mass, the ancient name of which is "Mount Ida," has an important place in the Greek mythology. "The Legend of Sarıkız," which emerged after Turks settled this region, indicates that the subalpine zone (i.e., the summit area) continues to attract people's attention (Bayat 2006). Thus, the natural forest cover was damaged. The subalpine layer did not emerge only because of natural factors, but also because of anthropogenic factors.

27.4 Findings and Discussion

Kaz Mountains (Mt. Ida) lies along the southwest-northeast direction. Its slopes mainly face south and north. On the south-facing slope, red pines (*Pinus brutia*) are widespread up to the elevation of 800 m. Above this elevation, there is the black pine (*P. nigra*) zone. On higher elevations, trees get sparse and shorter. The zone between 1600 and 1774 m has subalpine and pseudoalpine features (Pamukçuoğlu 1976).

The average annual temperature difference between the coastal zone and high zone is 8°C. While the average annual temperature in Edremit is 16°C, it drops to

8°C around the summit. On this level, different from the lower zone, there is a microclimate in which winters are frosty and snowy, and summers are cool.

There are three vegetation belts having characteristic features on Kaz Mountain. These are lowland, montane, and subalpine belts from bottom to top.

1-Lowland Zone This level goes up to 800 m above sea level on the south slope. Red pines (*P. brutia*) dominate this level. The part of the lower red pine zone (up to 350–400 m) was damaged due to anthropogenic effects, and maquis developed instead. And some parts were removed to establish olive groves. Among red pines, there are drought-tolerant plants such as downy oaks (*Quercus pubescens*), valonia oaks (*Quercus ithaburensis*), aleppo oaks (*Quercus infectoria*), and turkey oaks (*Quercus cerris*). The average annual temperature in the red pine zone ranges between 16 and 12°C.

The amount of annual precipitation ranges between 650 and 1000 mm. The bedrock is composed of schist limestones or granite. There are partially neutral and partially alcaline alluvial, colluvial, and brown forest soils.

The lowland zone on the North Slope begins at the elevation of 100 m and goes up to 500 m. The original vegetation consists of an oak forest. The dominant species are the Hungarian oak (*Quercus frainetto*) and the sessile oak (*Quercus petraea*). The average annual temperature on this belt ranges between 14 and 12°C. The amount of annual precipitation ranges between 650 and 850 mm. The bedrock is composed of basalt. Soils are mostly neutral or low acidic inceptisols.

2-Montane Zone On the south slope, this zone can also be called the black pine zone (*P. nigra*) and is located between the elevations of 800 and 1650. The average annual temperature ranges between 12 and 8°C. The amount of annual precipitation is 1000 mm on the lower level and 1450 mm on the higher level. The bedrock is composed of schist and Mesozoic limestones. Soils are low acidic inceptisols (pH 6.5).

This zone is located between the elevations of 500 and 1650 on the North Slope. Mainly beech (*Fagus orientalis*) and fir (*Abies nordmanniana* ssp.*equi-trojani*) forests comprise the vegetation. The average annual temperature ranges between 12 and 16°C. The amount of annual precipitation ranges between 850 and 1400 mm. The bedrock is composed of granite. Soils are low acidic and acidic inceptisols (pH 5.5–6.5).

3-Subalpine Zone The area located above 1650 m on the south slope and the area located above 1600 m on the north-facing slope are subalpine zones. There is no forest vegetation here. There are open areas covered with stocky and scattered trees, groups of bushes, and herbaceous plants.

27.4.1 Ecological Conditions of the Subalpine Zone

As the highest summit on Kaz Mount has an elevation of 1774 m, it does not have an alpine level. However, the upper forest boundary on Kaz Mountains is between 1600 and 1650 m. There is a subalpine belt with a relative height of 100–150 m.

Table 27.1 Fundamental ecological conditions, dominant vegetation, and species in the Kaz Mountain subalpine zone and other zones

Criteria	Slope	Vegetation zones		
		Subalpine	Montane	Lowland
Altitude	Northern	> 1600	500–1600	100–500
	Southern	> 1650	800–1650	0–800
Mean annual temperature (°C)	Northern	7–6	12–6	14–12
	Southern	8–7	12–8	16–12
Mean annual precipitation (mm)	Northern	> 1400	850–1400	655–850
	Southern	> 1450	1000–1450	667–1000
Bedrock	Northern	Schist, limestone	Granite	Basalt
	Southern	Schist, limestone	Schist, limestone	Schist, limestone, granite
Soil type	Northern	Podsolic	Limeless brown forest	Brown forest
	Southern	Podsolic	Limeless brown forest	Alluvial, colluvial, brown forest
Vegetation	Northern	Polster plants and mountain grass	Beech, fir forest	Oak forest
	Southern	Polster plants and mountain grass	Black pine forest	Red pine forest
Dominant species	Northern	*Acantholimon sp. Juniperus communis* ssp. *nana*	*Fagus orientalis*	*Quercus frainetto Quercus petraea*
	Southern	*Astragalus sp. Acantholimon sp.*	*Pinus nigra*	*Pinus brutia*

The subalpine zone approximately covers an area of 10 km^2 (1000 ha). It lies along 4.5 km from east to west and 2.5 km from north to south. In short, the belt is narrow and the area is small.

What makes up the characteristics of the subalpine level is the lack of a forest cover in a close and normal form. Yet, trees forming the forest have become dwarf and undergone deformation. These scattered trees grow up to a certain elevation. The tree line is on the highest point they can reach. This shows that the subalpine zone is the zone between the upper forest boundary and the tree line. Above 1450 m, dwarf, spiny, and cushion form alpine plant species can be observed. Dwarf trees are accompanied by leaning and short woody plants with deformed trunks (Schmithüsen 1968).

The subalpine zone of Kaz Mountain is represented by dwarf black pines (*P. nigra*). These occur even on the highest summit at elevation 1750 m. (Table 27.1)

The most common type of rocks in the subalpine zone of Kaz Mountain is green schist dating back to the Paleozoic Era. These are cleavage rocks that were horizontally and vertically split by diaclases. Therefore, they underwent physical decomposition and were split into flat bocks of various sizes. It was claimed that these blocks are in an order (stone rings called "the atrium of goose" by the public) and

Table 27.2 The south slope of Kaz Mountain, temperature and precipitation parameters of zones (Edremit Meteorology Station)

Months	Elevation levels (m)			
	Subalpine (1700 m)		Lowland (150 m)	
	(°C)	(mm)	(°C)	(mm)
January	−1.4	252.7	6.4	125.4
February	−0.8	225.5	7.0	98.2
March	1.2	132.7	9.0	75.3
April	5.7	108.1	13.5	50.7
May	10.8	94.8	18.6	37.4
June	15	22.6	23.1	14.3
July	17.7	13.5	25.5	5.2
August	17.2	12.9	25.0	4.6
September	13.6	85.4	21.4	20.1
October	8.2	119.2	16.0	53.9
November	3.5	177.6	11.3	112.3
December	0.5	266.4	8.3	139.1
Annual	7.6	1511.4	15.4	736.5

that these formations are related to periglacial conditions. Bilgin (1969) also stated that girland soils are present in the area. During the glacial period in the Pleistocene Era, the snow line in western Anatolia fell to 2200 m.

Around the summit of Kaz Mountain, marble and schist occur on in the same areas. For instance, the summit called Sarıkız (blond girl), which attracts attention thanks to its whiteness, is such a marble block. In addition, Babadağ and the Kırklar hill are hills where marble is observed.

In the subalpine zone of Kaz Mountain, the bedrock outcrops the surface and there is no soil cover in many parts of the surface. Shallow lithosols occur on severely eroded areas. As the area is high, physical actions such as sudden changes in temperature and frost effects are in effect in the decomposition of rocks. As a result, blocks and gravel emerge. Besides, the dominance of rocks such as schist that decomposes difficultly and limestone that melt prevents the formation and development of soils. Due to the wind effect, deflation is strong in the area which is composed of high plains. Thus, thin materials are wiped away and cannot be deposited.

In the subalpine zone, the elevation-caused change in precipitation and temperature created a different climate compared to that of the foothills of Kaz Mountain (Tables 27.2 and 27.3). The importance of aspect is great on this mountain in that its slopes face north and south (Table 27.2).

The southern slope is warmer than the northern slope. While the average annual temperature of the south slope in the subalpine area is 7.6°C, it is 6.3°C on the northern slope. There are groups of Kazdagi firs on the North Slope of the subalpine zone. The optimum average annual temperature for Kazdagi firs is around 8°C

Table 27.3 The North Slope of Kaz Mountains, temperature and precipitation parameters of zones (Bayramiç Meteorology Station)

Months	Elevation levels (m)			
	Subalpine (1700 m)		Lowland (150 m)	
	(°C)	(mm)	(°C)	(mm)
January	−2.9	220.3	4.6	100.9
February	−2.0	202.6	5.5	83.2
March	0.1	129.5	7.6	67.3
April	4.6	114.5	12.1	52.3
May	9.4	106.8	16.9	44.6
June	14.0	40.1	21.5	25.4
July	16.2	25.6	23.7	9.8
August	15.5	23.8	23.0	8.0
September	11.8	91.7	19.3	29.5
October	6.8	103.1	14.3	40.9
November	2.6	152.1	10.1	89.9
December	−0.4	241.3	7.1	121.9
Annual	6.3	1451.4	13.8	673.7

(Efe et al. 2010). Since temperature conditions are not suitable for firs in the subalpine zone, deformation in the forms of firs is observed.

A similar situation is present with black pines on the south slope. Because the optimum average annual amount of temperature for black pines is 10°C, the subalpine zone is the lowest temperature limit for these pines. The subalpine zone of Kaz Mountain is suitable for firs in terms of temperature, but the zone has marginal conditions for black pines (Efe et al. 2013a).

The amount of annual precipitation in the subalpine zone of Kaz Mountain is around 1500 mm. The optimum amount of annual precipitation for firs and black pines is 1400 and 1000 mm, respectively. Based on this data, it can be said that precipitation does not have an adverse effect on both species. Summer drought is not severe in this area.

When temperature and precipitation factors are considered, it is possible to say that there are suitable conditions for Kazdagi fir (*A. equi-trojani*) in the subalpine zone. However, it is possible to state that temperature conditions are not suitable for black pines (*P. nigra*). This unsuitability is also the primary reason why the forms become dwarf and undergo deformation.

The subalpine zone of Kaz Mountain is the area where rivers flowing towards the north and south take their sources from. The summit line makes up the watershed. Lithologic structure has an important role in leak of water. Although schist is an impermeable rock, it has many diaclases around the summit area. The same goes for the marble. Moreover, marble and limestones are rocks that can dissolve.

The fact that the marble and schist outcrop in summit area increase the infiltration of water. For this reason, precipitation falling as snow and rain feeds ground water rather than make up surface water. Water surfaces from strong and cold springs on both slopes.

The Zeytinli, Kızılkeçili, Fındıklı, Şahindere, Mıhlı streams which flow towards the south and subsidiaries which join the Karamenderes and Tuzla streams by flowing towards the north feed from the subalpine zone of Kaz Mountain. There are about ten water springs in the subalpine zone, which are mostly contact springs. In the area, ground water surfaces as springs and sources on marble (limestone) schist contacts. The one on the highest location is the Kartal spring or Kartalçeşme. It surfaces at the elevation of 1730 m. This source was formed on the schist-marble contact.

The subalpine zone of Kaz Mountain is visited by many species of vertebrate mammals occasionally during their annual life cycle. Many species of the mammal fauna, including brown bears (*Ursus arctos*) which are the biggest mammals on the mountain, have the chance to live here. The habitats of these animals can be grouped into forest habitats, forestsides, and polster plant habitats; herbaceous habitats and rock habitats. Illegal hunting has caused many species of Kaz Mountain fauna to disappear (Table 27.4).

27.4.2 Vegetation Characteristics of the Kaz Mountains Subalpine Zone

On the south-facing slope of the subalpine zone are observed degraded, deformed, and dwarf coniferous trees, cushion shaped and aerodynamic bushes, and plant communities consisting solely of herbaceous plants.

27.4.2.1 Degraded Coniferous Trees

This degraded community composed of Black pines (*P. nigra*) on the south slope appears between the elevations of 1650 and 1774 m. Trees became sparse, dwarf, and deformed due to low temperatures, strong winds, and unsuitable soil conditions. The average annual temperature on the south slope of the subalpine zone is 7.6°C, and this is the marginal value for black pines. The optimum average annual temperature for black pines is around 12°C (Efe et al. 2013b).

The average annual temperature on the northern slope of the subalpine zone is 6.3°C, and here there are black pines and Kazdagi firs that have become dwarf (Table 27.3). Short and single black pines can be observed up to 1690 m, while Kazdagi firs can be observed up to 1600 m.

Even though the amount of precipitation is enough on the North Slope of the subalpine zone, low temperatures have an adverse effect on tree growth. Black pines and Kazdagi firs can endure low temperatures (temperatures between −20 and −25°C). But, summer temperature that is need for these trees to grow is not enough in terms of duration and degree. Therefore, these trees remain as dwarfs,

Table 27.4 Flora list of subalpine zone of Kaz Mountain

Scientific name	Family	Characteristics and form
Abies nordmanniana (STEV.) SPACH ssp. *equi-trojani* (ASCHERS. ET SINT. EX BOISS.) COOD. ET C	Pinaceae	Tree
Acantholimon ulicinum (WILLD. EX SCHUL-TES) BOISS	Plumbaginaceae	Polster bush
Allium kurtzianum [ASCHERSON & SINT. EX] KOLLMANN	Liliaceae	Herbaceous
Armeria trojana BOKHARI ET QUEZEL	Plumbaginaceae	Herbaceous
Asperula sintenisii ASCHERSON EX BORNM	Rubiaceae	Succulent herbaceous
Astragalus heldreichii BOISS	Fabaceae	Polster herbaceous
Astragalus idae SIRJ	Fabaceae	Polster bush
Asyneuma limonifolium (L.) JANCHEN ssp. *limonifolium*(L.) JANCHEN	Campanulaceae	Herbaceous
Asyneuma virgatum (LABILL.) BORNM. ssp. *virgatum* (LABILL.) BORNM	Campanulaceae	Herbaceous
Centaurea athoa DC	Asteraceae	Herbaceous
Cerasus prostrata (LAB.) SER. var. *prostrata* (LAB.) SER	Rosaceae	Bush
Chamaecytisus ariocarpus (BOISS.) ROTHM	Fabaceae	Bush
Crataegus stevenii POJARK	Rosaceae	Bush
Crocus gargaricus HERBERT ssp. *gargaricus*	Iridaceae	Geophyte herbaceous
Daphne oleoides SCHREBER ssp. *oleoides* SCHREBER	Thymelaeaceae	Bush
Dianthus arpadianus ADE ET BORNM	Caryophyllaceae	Polster herbaceous
Dianthus erinaceus BOISS. var. *alpinus* BOISS	Caryophyllaceae	Polster herbaceous
Drababruniifolia STEV. ssp. *olympica* (SIBTH. EX DC.) COODE ET CULLEN	Brassicaceae	Polster herbaceous
Echium russicum J. F. GMELIN	Boraginaceae	Herbaceous
Ferulago idae N. OZHATAY ET E. AKALIN	Apiaceae	Herbaceous
Genista anatolica BOISS	Fabaceae	Bush
Hypericum kazdaghensis GEMICI ET LEBLEBICI	Clusiaceae	Herbaceous
Iberis saxatilis L	Brassicaceae	Polster herbaceous
Jasione idaea STOJ	Campanulaceae	Herbaceous
Juniperus communis L. ssp. *nana* SYME	Cupressaceae	Groundcover bush
Linum boissieri ASCHERS. ET SINT. EX BOISS	Linaceae	Polster bush
Minuartia garckeana (ASCHERS. ET SINT. EX BOISS.) MATTF	Caryophyllaceae	Cluster herbaceous
Muscari bourgaei BAKER	Liliaceae	Geophyte herbaceous
Papaver pilosum SIBTH. ET SM. ssp. *stric-tum* (BOISS. ET BALANSA) WENDT EX KADEREIT	Papaveraceae	Herbaceous

Table 27.4 (continued)

Scientific name	Family	Characteristics and form
Parnassia palustris L	Saxifragaceae	Herbaceous
Paronychia sintenisii CHAUDHRI	Caryophyllaceae	Cluster herbaceous
Pinus nigra J. F. ARNOLD ssp. *pallasiana* (LAMB.) HOLMBOE	Pinaceae	Tree
Rosa pulverulenta BIEB	Rosaceae	Bush
Rosa sicula TRATT	Rosaceae	Bush
Saxifraga sancta GRIS	Saxifragaceae	Cluster herbaceous
Scabiosa columbaria L. ssp. *columbaria* L. var. *columbaria* L	Dipsacaceae	Herbaceous
Scillabifolia L	Liliaceae	Geophyte herbaceous
Scutellaria orientalis L. ssp. *alpina* (BOISS.) O. SCHWARZ var. *alpina*(BOISS.) O. SCHWARZ	Lamiaceae	Cluster woody
Sedum album L	Crassulaceae	Succulent cluster herbaceous
Sedum dasyphyllum L	Crassulaceae	Succulent cluster herbaceous
Sedum lydium BOISS	Crassulaceae	Succulent cluster herbaceous
Sideritis trojana BORNM	Lamiaceae	Herbaceous
Silene bolanthoides QUEZEL, CONTANDRIO-POULOS ET PAMUKÇUOĞLU	Caryophyllaceae	Cluster herbaceous
Silene falcata SIBTH. ET SM	Caryophyllaceae	Cluster herbaceous
Thymus cherlerioides VIS. var. *cherlerioides* VIS	Lamiaceae	Cluster woody
Thymus pulvinatus CELAK	Lamiaceae	Groundcover woody
Thymus sipyleus BOISS. ssp. *Sipyleus* BOISS. var. *sipyleus* L.	Lamiaceae	Groundcover bush
Trifolium fragiferum L. var. *fragiferum* L.	Fabaceae	Cluster herbaceous
Tulipa sylvestris L.	Liliaceae	Geophyte herbaceous
Veronica chamaedrys L.	Scrophulariaceae	Cluster herbaceous
Viola tricolor L.	Violaceae	Herbaceous

and effective winds deform them (Tables 27.2 and 27.3). The vegetation period for broadleaved tree species is very short, so they are not observed in the area.

27.4.2.2 Woody Bushes and Polster Plants

These are leaning halophyte woody plants which have a xeromorphic appearance and are found up at most to half a meter above the aerodynamically shaped ground. They are in bush form. Their distribution is different on the north and south subalpine slopes. The most common and characteristic one is dwarf juniper (*Juniperus communis* ssp. *nana*). These are ground-cover trees that are common and dominant in the northern section, but they decrease in number towards the south. Junipers characterize the subalpine zone of Kaz Mountain (Pamukçuoğlu 1976).

Daphne oleoides is another common species. It is short and cushion form, and occurs as groups. Its wood is hard, and leaves are fleshy and hard. They are dispersedly distributed and decrease in number towards the south.

Astragalus (*Astragalus idea*) represents the south of the mountain subalpine zone (Tümen et al. 2007). They form groups in some places and decrease in number towards the north.

Acantholimon ulicinum grows on the driest grounds of this zone. They are more common in the north and decrease in number towards the south. These plants are polster and xeromorphic and are dispersedly distributed.

Species such as mountain wild cherries (*Cresus prostrata*), *Crataegus stevenii*, and *Chamaecytisus ariocarpus* are sparsely observed. Rose species such as *Rosa canina*, *Rosa pulverulenta,* and *Rosa sicula* are other stocky bushes grow in the area. Three bushy thymus species (*Thymus cherlerioides*, *Thymus pulvinatus*, and *Thymus sipyleus*) were observed in the middle and southern sections of the subalpine zone. *Linum boissieri* is a calcicol woody plant which was noted in the area (Table 27.4).

In this zone where winds are effective, woody plants took aerodynamic shapes. They leaned or took the form of groups or cushion. Ground drought, insufficient temperatures, shortness of the vegetation period, thinness or lack of soils caused these plants to remain short and have xeromorphic characteristics.

27.4.2.3 Herbaceous Species

There is not an unceasing grass cover (meadow) on the subalpine level of Kaz Mountain. Grass cover is common among bushes, in some large treeless areas, places where winds are most effective, and on rocky grounds with very thin soils. This grass cover is defined as "Pelouses écorchés" in some sources (Efe 1998).

This vegetation is buried under the snow cover in winter. It begins to reappear in the beginning of April, and functions until it is covered with snow again. However, the vegetative activity season of each species is different. This cover is mostly composed of flowery grass and contributes a pleasant landscape to the subalpine zone.

Most of grass is lithopytic and hasmophytic groups of grass clinging to rock surfaces and fractures. Two species of mountain dianthus, namely, *Dianthus arpadianus* and *Dianthus erinaceus* var. *alpinus*, are typical examples of this species. Furthermore, *Draba brunifolia* ssp. *olympica*, one of the calcicol plants on the Sarıkız hill, is a typical hasmophyte (Figs. 27.2 and 27.3).

Some species consist of succulent grass with fleshy leaves. Sedums (*Sedum album*, *Sedum dasyphyllum*, and *Sedum lydium*) and *Asperula sintenisii* are dominant species in this area. Some crocus (*Crocus gargaricus*) and tulip species (*Tulipa sylvestris*) are the geophytes of the subalpine zone appearing in spring, summer, and fall (Fig. 27.4).

Total of 24 endemic species belonging to 15 family were noted in the study area (Table 27.5). Nine of them are endemic to Kaz Mountains, and 15 species endemic

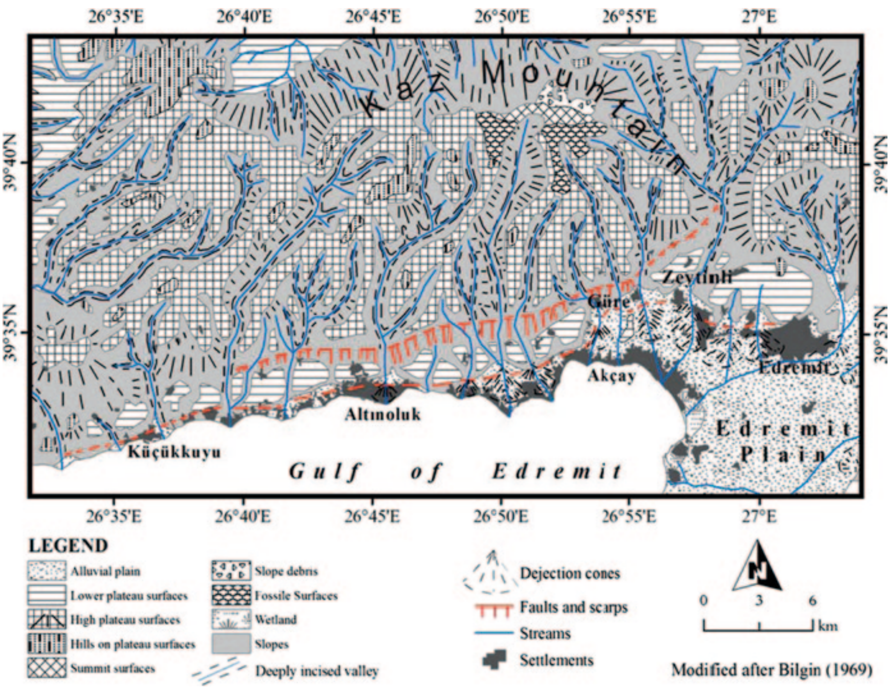

Fig. 27.2 Geomorphological map of Kaz Mountain

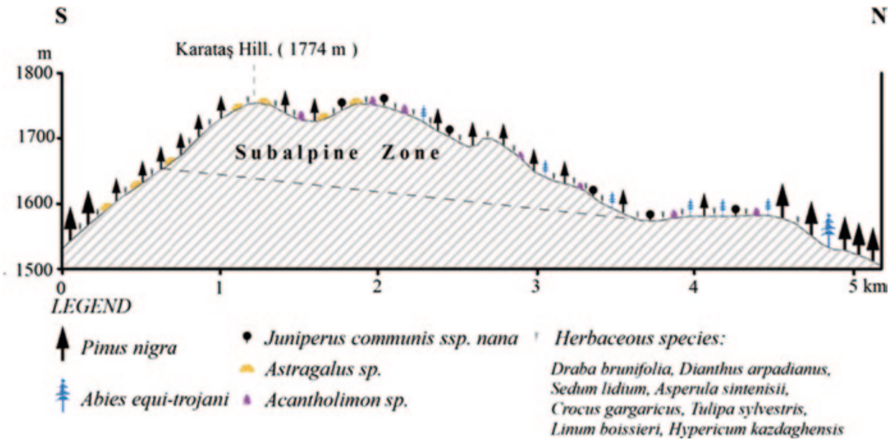

Fig. 27.3 Vegetation cross section of the subalpine zone of Kaz Mountain

to Turkey. Endemic species occur mostly at the elevation between 1700 and 1750 m (Table 27.5). Some species such as *Dianthus erinoceus* Boiss. var. *alpines* Boiss, *Ferulago idea* N. Özhatay & E. Akalın, *Linum boissieri* Asch. & Sint. Ex Boiss., *Silenebol anthoides* Quezel, Contandriopoulos & Pamukçuoğlu. Grows only in limited areas in subalpine zone.

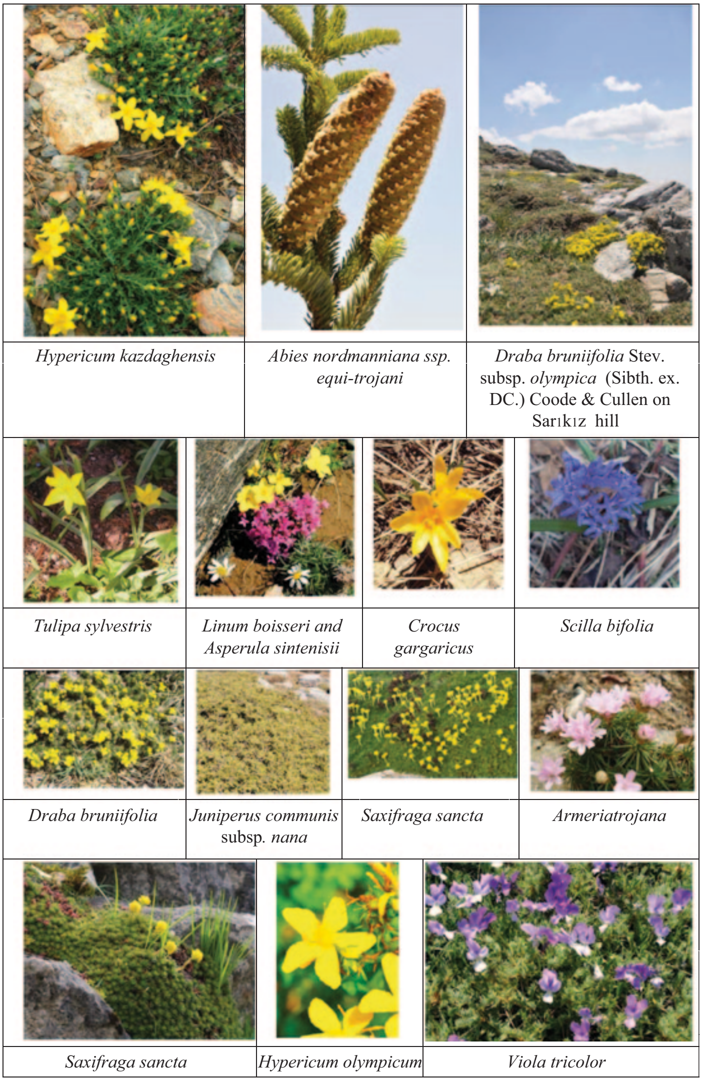

Fig. 27.4 Plant species on the higher parts of Kaz Mountains

27.4.3 Anthropogenic Effects on the Subalpine Zone

Ida Mountain and the surrounding area is a district used by people for thousands of years. Troy, Adramytieon, Thebe, Astyra, Antandros, Gargara, Assos, Lamponia, Scepsis, Scamandria, Kergene, Kebrene, Pionia, Kergis, Troas, Neandria, and Argisa are the ancient cities situated around Kaz Mountains (Efe et al. 2014). As Troy dates back to 3000 BC (Rix 2002; Umar 2002), it is understood that the area has been settled for at least 5000 years.

Table 27.5 Endemic plant species in subalpine zone in Kaz Mountain (Mt.Ida)

Name of taxon	Family	Habitat and altitude
Abies nordmanniana (Stev.) Spach ssp. *equi-trojani* (Asch. & Sint. ex. Boiss.) Coode & Cullen[b]	Pinaceae	1000–1700 m Northern slope
Allium kurtzianum (Asch. & Sint. ex) Kollman[b]	Liliaceae	1500–1750 m
Armeria trojana Bokhari & Quezel[b]	Plumbaginaceae	1500–1700 m
Asperula sintenisii Ascherson ex Bornm[b]	Rubiaceae	1600–1750 m
Astragalus idea Sirj[b]	Fabaceae	1600–1750 m
Astragalus heldreichii Boiss[a]	Fabaceae	1300–1700 m
Asyneuma virgatum (Labill.) Bornm. ssp. *cichoriiforme* (Boiss.) Damboldt[a]	Campanulaceae	700–1700 m
Corydalis wendelboi Lidén ssp. *congesta* Lidén & Zetterlund[a]	Papaveraceae	700–1700 m
Crocus biflorus Miller ssp. *nubigena* (Herbert) Mathew[a]	Iridaceae	200–1700 m
Crocus gargaricus Herbert ssp. *gargaricus*[a]	Iridaceae	1300–1700 m
Dianthus erinoceus Boiss. var. *alpinus* Boiss[a]	Caryophyllaceae	1700 m
Ferulago idea N. Özhatay & E. Akalın[b]	Umbelliferae	1750 m
Hypericum kazdaghensis Gemici & Leblebici[b]	Hypericaceae	1500–1700 m
Iris kerneriana Asch. Sint. ex Baker[a]	Iridaceae	900–1700 m
Jasione idaea Stoj[b]	Campanulaceae	1350–1700 m
Linum boissieri Asch. & Sint. Ex Boiss[a]	Linaceae	1700 m
Muscari bourgaei Baker[a]	Liliaceae	1500–1700 m
Muscari latifolium Kirk[a]	Liliaceae	1100–1750 m
Onosma bracteosum Hausskn. & Bornm[a]	Boraginaceae	300–700 m
Onosma nanum DC[a]	Boraginaceae	0–1700 m
Sedum lydium Boiss[a]	Crassulaceae	1500–1700 m
Sideritis trojana Bornm[b]	Lamiaceae	1500–1720 m
Sileneba lanthoides Quezel, Contandriopoulos & Pamukçuoğlu[b]	Caryophyllaceae	1700 m
Stachystmolea Boiss[a]	Lamiaceae	200–1700 m

[a] Endemic to Turkey
[b] Endemik to Kaz Mountains

People have known Mount Ida since then and benefitted from it in various ways. The mountain has mostly been used for timber and animal husbandry.

Goat, sheep, cattle, and horse herds have been fed since the early ages of history. Among the findings belonging to the ancient cities of the regions are coins on which figures of the above-mentioned animals are inscribed (Serdaroğlu 2005). There is no doubt that Kaz Mountain has been used as a highland for thousands of years. The fact that cheese making of the region is very popular can be regarded as a result of traditional animal husbandry.

After Turks (Oghus Turks-Semi-nomadic tribes) arrived in the region, these activities became even more intense. The extreme use of mountain meadows damaged their floristic composition and weakened the vegetation. Composition of the vegetation varies with landscape position, aspect, and grazing history.

Fieldwork conducted in the subalpine zone revealed that very spiny, bulbous, extremely aromatic, and even poisonous grass species are more common than forage. The weakening of the grass cover led to the exacerbation of deflation.

Timber trees including black pine, fir, beech, and chestnut are common on the northern slopes. These trees have been cut down for various purposes for thousands of years (Özdemir 2008).

Local people have enshrined Mount Ida since ancient times. After Turk arrived, enshrinement of the mountain continued with the "Legend of Sarıkız." There is a place called Sarıkız on the mountain. This place stands like a pyramid in the subalpine zone of Kaz Mountain. Yellow wildflowers blossom around in spring. Many years ago, particularly on certain days, people of Güre and Kavurmacılar villages used to go to Sarıkız hill. Then, this tradition spread to other villages in the area. Today, it is an annual festival that is attributed to Tahtacı and Çetmi Turkomans live in the region and to the western Anatolian Turkomans.

There were many historical paths in the subalpine zone of Kaz Mountain. These were connected to Bayramiç and Kalkım districts in the north. Roads beginning from Altınoluk and Zeytinli in the south and going up to the summit were used in the past. All of these can be presented as evidence of the immense effects of anthropogenic factors has on the subalpine zone of Kaz Mountain.

27.5 The Effects of a Possible Climate Change on Subalpine Zone

Research results show that a periglacial section emerged in the Kaz Mountain during the Pleistocene Period. These periglacial marks have reached even the modern times (Bilgin 1969). In that period, snow line in Turkey's western Anatolia shifted down to 2200 m (Erinç 1971). It dropped to around 1650 m in the Periglacial zone of the Kaz Mountain. This area has a tundra-like vegetation composed of arctic-alpine elements. The upper forest line fell to 1650 m, which is the lower limit of the periglacial layer. The lower forest line of this boreal forest made up of coniferous tree species is 1200 m. The Kaz Mountain fir (*A. nordmanniana* ssp. *equi-trojani*), today an endemic coniferous plant, appeared under the conditions of that period. In the past, the Kaz Mountain firs were more widely distributed. Their area has gradually shrinked in size due to temperature increases caused by global warming.

Today, there is a subalpine zone in the Kaz Mountain formed by the effects of the orographic factors. The area of the Kaz Mountain firs got smaller. The beech community took shelter on the northern slope. Yellow Azalea (*Rhododendron flavum*) groups, which spread in the area during the Pluvial Period, remained as small groups of relict in areas dominated by special edaphic conditions.

Due to the climate change, it is difficult for the vegetation belts in the Kaz Mountain to move upwards as a whole. Instead, there will be local shifts. A 2°C increase in area temperature equals to a difference of 400 m in altitude. As a result, it will cause some competitive plants species growing in lower parts to come to the area and the extinction of plant species in some areas. Turkish pines (*P. brutia* Ten.) can be expected to reach 1000 m. On the other hand, black pines (*P. nigra*) and the Kaz Mountain fir (*A. nordmanniana* ssp. *equi-trojani*) are likely to go up to 1100 and 1500 m, respectively.

In case of a climate warming, the subalpine zone will be destroyed, making the Kaz Mountain fir zone even smaller. Firs will move towards higher and more secluded areas and perhaps disappear. The lower limit of the beech zone will go higher, and its area will get narrower. Meanwhile, hygrophilous species will grow fewer in number, and the flora will no longer be hygrophilous. *R. flavum* highly likely to fail to flourish in the area. The vegetation on the northern slopes will lose its hygrophilous characteristics, and the flora will be deprived of its richness.

The southern slope will be even warmer. The upper limit of *P. brutia* will reach 1200 m. *P. nigra* will only be able to grow above this level and cover each and every corner up to the summit. They will reach the northern slope and be the only dominant element there. The vegetation will assume even more xerophytic characteristics, and the flora will be poorer. Xerophytic species with an affinity for high temperatures will prevail in the area.

Conclusions

Mountainous regions are more prone and sensitive to climate changes. Thus, these fragile ecosystems must be analyzed better than other areas, and damage in case of a climate change must be minimized.

There is a subalpine or pseudoalpine zone, formed by natural factors in the area above 1650 m on Kaz Mountains. Climate, elevation, and bedrock are the main factors determining the features of this zone. There is a difference between the northern and southern parts of the mountain in terms of the amount of precipitation and temperature. The North Slope receives more precipitation, and the average annual temperature on the North Slope is 1.3°C colder than that of the south slope. The average temperature of the coldest month is −1.4°C on the south slope and −2.9°C on the northern slope. A large amount of snow falls in winter, and the amount of annual precipitation reaches 1500 mm in the area. Rocks cut through by diaclases cause the amount of infiltration to increase. Thus, the area is rich in surface and ground water and springs. Slope and contact sources are common in the area.

Metamorphic rocks such as schist and marbles and granitic rocks cutting through them are common in the area. Physical dissolution occurs in the subalpine zone due to daily and seasonal temperature differences. Soil cover is thin, and soils are acidic. Due to natural and anthropogenic erosion, bedrock surfaced in many sections on higher parts of the mountain.

Black pines occur up to the summit of the mountain in this subalpine area. However, they are short and deformed. Kazdagi firs (*Abies equis-trojani*) occur on the North Slope. On the south slopes, there is a plant community consisting of cushion form species, grouped grass, perennials, and dwarf woody species. The dominant member of this community is the dwarf juniper (*J. communis* ssp. *nana*). Groups of herbaceous plants and geophytes are abundant on rocky surfaces and between cracks. The area is also rich in endemic species. Composed of cushion form bushes, herbaceous plants, and other plants, this community is defined as a subalpine meadow or P. écorchés.

There is a very rich fauna made up of vertebrates and invertebrates in the subalpine zone. This fauna contains traveling and migratory species that occasionally visit here and species that dwell here. Even though the subalpine zone of Kaz Mountain emerged due to natural conditions, anthropogenic factors also have an impact on the formation of this region, which is inhabited by at least 5000 years.

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Chapter 28
Creeping Environmental Problems in the Pamir Mountains: Landscape Conditions, Climate Change, wise Use and Threats

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Access to a secure, safe and sufficient source of fresh water is a fundamental requirement for the survival, well-being and socio-economic development of all humanity. Yet, we continue to act as if fresh water were a perpetually abundant resource. It is not.
Kofi Annan, Is the World Running Out of Water?, Awake! magazine, June 22, 2001

28.1 Introduction

Pamir is a highland region in Central Asia, located on the orogenic uplift known as the Pamir Knot which joins several Asian mountain ranges. The name Pamir may derive from the ancient Iranian *pai-mir,* "foot of Mithra," god of the sun or from the word *pamers*, which means the flat and wide high valleys with typical mountain meadows in altitudes around 3500–4000 m above sea level (a.s.l.) High mountain topography (the highest ranges exceed 7000 m a.s.l.) is a characteristic feature of this region and acts as a barrier isolating it from the rest of the world.

Due to its geographical location, extreme climatic conditions (cold desert biome), isolation, and exceptionally short growing season, high-mountain ecosystems of the Pamir Mountains developed a unique landscape and natural characteristics. Among a diversity of habitats such as lakes, rivers and streams, alpine meadows, steep mountain slopes, and permanent glaciers, many play an important

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Fig. 28.1 Geographical and topographical position of the Pamir Mountains

role as refuges for numerous endemic species of plants and animals, crucial forage grounds, and the only available stopovers for migrating birds in the high mountains (Breu and Hurni 2003; Farrington 2005; Timmins 2008).

The Pamir Mountains are an important area of exceptionally high mountain glaciers in the arid regions (continental glaciers). Permanent glaciers cover approximately 10–13 % of the total area of the Pamir, with the surface currently estimated at 8000 km^2. Among various types of glaciers developed in the Pamir Mountains, there are huge dendrite glaciers (e.g., the Fedchenko Glacier), surging glaciers (e.g. the Medvezhiy Glacier), as well as cirque or niche glaciers, and ice caps. Being so strongly glacierized, Pamir is the main source of water for the central Asian lowlands. Both glacier and snowmelt waters feeding mountain rivers contribute 65 % of the total inflow into the Aral Sea basin, thus supporting the irrigated agriculture in Central Asia (Aizen 2011; Shiene and Mirzabaev 2009; Rojan 2007; Kayumov 2006).

With the expected increase in air temperatures and changes in precipitation patterns, observed glacier recession will become more intense, eventually leading to

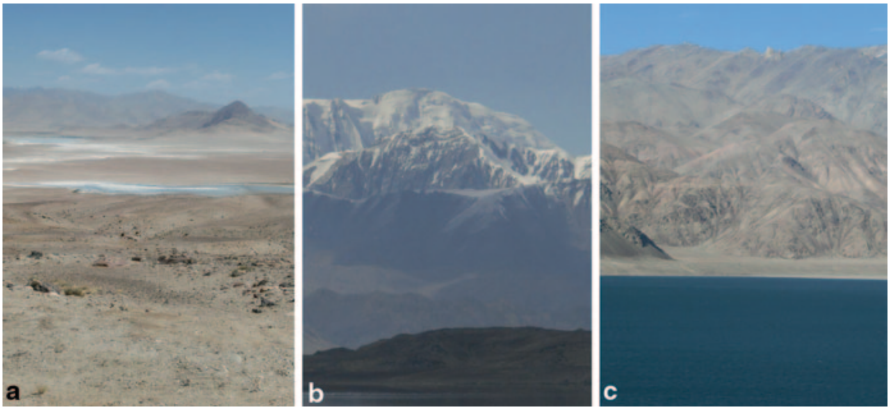

Fig. 28.2 Landscapes of the Pamir mountains. **a** high mountain plateau with saline lakes in the Eastern Pamir; **b** high, glaciarized mountains in the Western Pamir; **c** Yashilkul lake and desert mountains surroundings

dramatic decrease in the river runoff. Insufficient amounts of water reaching the downstream countries (Uzbekistan, Turkmenistan, Kazakhstan) will lead to further devastation of environment and growing political tensions between the water users (Shiene and Mirzabaev 2009).

28.2 Geographical and Climatic Conditions

The Pamir Mountains, which include the Eastern Pamir, the Western Pamir, and the Pamir-Alai Mountains, are linked to the highest mountain systems of Central Asia and the world, being bordered by Hindukush in the south, Karakorum and the Himalayas in the southeast, Kunlun in the east, Tien Shan in the north, and Parapamir in the west (Fig. 28.1). Pamir covers an area of some 65,000 km², with over 90% of the land situated within the Gorno-Badakshan Autonomous Oblast of Tajikistan. Pamir elevation and terrain are very diverse, ranging from 300 m a.s.l. in the region of the lower Amu Darya River, to up to 7700 m a.s.l. in its chinese part, with an average elevation of about 3965 m a.s.l.

Pamir landscapes developed under strong influence of topography and climatic patterns. Their diversity reflects altitudinal zonation and relief changes in the eastern and western parts of the Pamir Mountains, combined with climatic characteristics—sharply decreasing precipitation and increasingly continental climate as one moves from the northwest to the east and southeast (Shahgedanova 2002, Fig. 28.2).

The relief of the Western Pamir is characterized by large relative elevations and narrow valleys with steep slopes. The highest summit of the Tajik Pamir, Peak Somoni (7495 m a.s.l.), and the largest alpine glacier, Fedchenko (on the junction of the Peter the First and the Academy of Science ridges), are located there. The Eastern Pamir is a highly elevated plateau. The ancient relief has survived here in the form of vast flat valleys elevated to the height of 3500–4000 m a.s.l., on which permafrost develops (Shahgedanova 2002). Most territory of the Pamir Mountains is barren, rocky mountain terrain with permanent snow, glaciers, and debris. There are almost no trees, and the flora consists of low plants adapted to harsh conditions.

28.2.1 Climate conditions

The Pamir Mountains have a severe continental high-mountain climate, especially in the east, where enclosed depressions retain cold air. Because the Pamir Mountains are located in the subtropical belt, air masses from the temperate latitudes predominate here in winter and tropical air masses predominate in summer. The ridges of the highest mountain systems in the Western Pamir, Hindukush, and Himalaya form a barrier against moisture borne by winds from the Indian and Atlantic Oceans, thus shaping a continental climate characterized by sharply contrasting temperature regimes and markedly seasonal precipitation (Vielicko and Spasskaa 2011).

The climate of the Pamirs is arid continental and is characterized by significant seasonal and daily temperature fluctuations, specific relative humidity, and other meteorological elements. Precipitation greatly depends on the direction of mountain ranges, as well as air masses circulation. The Eastern Pamir is known for its cold and arid climate (mean annual precipitation range between 50–150 mm), while the Western Pamir receives 2000–2500 mm and the Central Pamir (the highest part of the Western Pamir, according to Aizen 2011) 800–1500 mm of precipitation annually (Kayumov and Rajabov 2008; Aizen 2011).

The high-mountain regions of the Western Pamir are known for their unstable climate. Average temperature here is close to zero, and only in the lower reaches does it rise up to + 6 °C– + 8 °C. The Eastern Pamir is distinguished with its extreme severe climate. The annual temperature here is mainly below zero and makes −1 °C–−6 °C. The absolute minimum was observed within the surroundings of Bulunkul Lake, − 63 °C (Tajik Met Service). By contrast with the Western Pamir, rainfall in the Eastern Pamir increases during summer, whereas in most winters the high plateaus get no snow. As a consequence of smaller precipitation rates, combined with high radiation, strong winds, and subzero average temperatures from October to March, the Eastern Pamir must be regarded a mountain desert with strongly arid and semi-arid climate conditions.

Mean air temperature in the Pamir Mountains was increasing, at the rate of about 0.1 °C per decade between years 1940 and 2000 and 0.34 °C per decade between 1979 and 2000 (Chevallier et al. 2012). In high mountains, climate warming is much faster, reaching 2.0–2.4 °C per decade at the altitude of 7000 m a.s.l. (Tian et al. 2006). Along with temperature growth the aridity of Central Asia is expected to increase, leading to severe droughts (Lioubimtseva and Henebry 2009).

Table 28.1 Characteristics of glaciers in the Tajik Pamir. (Aizen 2011; Rojan 2007)

	Western Pamir	Central Pamir	Eastern Pamir
Annual precipitation [mm]	2000–2500	150–800	50–150
ELA [m a.s.l.]	3600–4000	4400–4800	4800–5200
Glaciation surface [km^2]	Total surface for Western and Central Pamir: 6110		1454
Dominating types of glaciers	Avalanche and cirque glaciers	Dendrite and surging glaciers	Ice caps, slope and niche glaciers
Moraine debris coverage	High	High	Low
Dominating type of firn	Warm	Cold	Cold

28.3 Hydrology of the Pamir Mountains

28.3.1 Glaciers and Rivers of the Pamir Mountains

28.3.1.1 General Characteristics

Contemporary glaciation in the Tajik Pamir covers 10–13 % of the total area of this massif. Its surface is currently estimated at 8000 km^2, with even 1000 km^2 differences between texts by various authors (Rojan 2007; Kayumov and Rajabov 2008; Dolgushin and Osipova 1989). Glaciers are formed under relatively dry conditions and therefore belong to a continental type, characterized by, negative average annual temperature of ice at all depths, and melting limited only to upper layers. Their form and characteristics vary, following climatic differences between certain parts of the Pamir Mountains (Aizen 2011; Kayumov and Rajabov 2008). The main distinctions between glaciation in the western, central, and eastern part of the Tajik Pamir are shown in Table 28.1.

The largest glacier in the Pamir Mountains is the Fedchenko glacier, located in the central part of the massif. It is also the world's largest alpine glacier outside the polar regions. It originates at 6200 m a.s.l. and its terminus stretches to 2910 m a.s.l. Its length exceeds 70 km, width—2 km and maximum ice thickness—1 km. The total area covered by the glacier and its tributaries is 714 km^2 and their total volume—140 km^3 (Aizen 2011; Kayumov and Rajabov 2008).

Glaciers of the Pamir Mountains play an important role in forming the Amu Darya River, the largest river in Central Asia (2400 km long, 534,739 km^2 of the total basin area), which supplies water to over 60 million people in Tajikistan, Uzbekistan, Turkmenistan, Afghanistan, and Xinjiang province of the People's Republic of China, and provides 65 % of inflow into the Aral Sea (Aizen 2011; Kayumov and Rajabov 2008). Sources of the Amu Darya are located in the glacierized high-mountain areas in Tajikistan, Kyrgyzstan, and Afghanistan, and include the upper

Table 28.2 Annual flow rates of the chosen Pamir rivers. (after Pulatov 2006)

River basin	Gauging station	Annual flow in 2004 [km^3]
Kyzylsu	Somonchi	1.30
Vakhsh	Nurek Dam	22.04
Panj	lower Panj	39.21
Surkhob	Garm	9.40
Gunt	Khorog	3.07
Bartang	Shudjant	4.20
Vanch	Vanch	1.66

catchments of the Surkhob River, the Obihingou River, and the Panj River. The Surkhob and Obihingou rivers join into the Vaksh river, which in turn is a tributary to the Panj River, forming the Tajik-Afghan border. After the confluence of Panj and Vaksh, the river continues as Amu Darya (Mergili et al. 2013).

As far as drainage is concerned, the area of the Tajik Pamir can be divided into three basins: (1) basin of the Panj and Kyzylsu rivers (including the rivers Panj, Kyzylsu, Vanch, Bartang, Gunt, Pamir, and Oksu), with the maximum average flow in April (southwestern part of the basin) and July (eastern part of the basin); (2) basin of the Vaksh river (including the rivers Vaksh, Obihingou, Surkhob, Muksu, and western part of Panj), with the maximum average flow in July (southern part of the basin) and August (northern part of the basin); (3) basin of the Karakul lake and the Marakansu river (Tajik Met Service). Annual flow rates for the chosen Pamir rivers are given in Table 28.2.

Most of the Pamir's rivers have glacial-snow regimes, characterized by flow lasting up to 7 months in the year, with the largest volumes of water in July and August. At the lower elevations there are also snow-rainwater rivers, with flow lasting 4 months, with a peak in April (Tajik Met Service). During flood season (April-August) the mountain rivers carry huge amounts of suspended solids, which can exceed 5 kg/m^3 (Kayumov and Rajabov 2008).

28.3.1.2 Impact of Climate Warming

Though the massif of Pamir belongs to the most strongly glacierized mountains in the world, since the end of the Little Ice Age glaciers of Pamir have been retreating. The rate of their recession varies, depending on climatic and geomorphological factors (Aizen 2011; Rojan 2007). In the western part of the Pamir Mountains, glacier retreat is the most intensive—during the last 50 years the glaciations in the basin of the Vanch River reduced by more than 25–30 %. Located in the central part of the massif, the Fedchenko glacier is estimated to have lost 6 % of its total area (44 km^2) during the last 50 years and sunk 50 m. The Garmo glacier (also in the central part of the massif) has retreated 7 km from 1932–2007 (retreat speed 100 m/year!). Recession was also confirmed for the glaciers Fortambek, Surgan, Mushketov, Bolshoi

Saukdara, Skogach, and Bartud. Glacial degradation in the eastern part of the Pamir Mountains is less intensive, yet confirmed for the Akbaital Glacier and glaciers of the Murghab river basin (Aizen 2011; Kayumov and Rajabov 2008).

As a result of deglaciation in the Pamir Mountains, the river runoff increased by 2% during the last decade. It is expected that with the further melting of glaciers, the inflow to the Panj, Vaksh and, eventually, the Amu Darya River will increase, and then, in the long-term perspective, dramatically decrease due to the glacial deficit (Aizen 2011; Kayumov and Rajabov 2008). According to Perelet (2007), the devastating impact on the regional water resources will take place quite soon, and by 2050 the Amu Darya River may decrease by 40%. On the contrary, Severskiy (2007) assumes that glaciers in the Pamir Mountains will recede, yet will not completely disappear and the reserves of underground ice will be equivalent to the present day glacier resources. Some authors (e.g. Schetinnikov 1998) also underline that it is difficult to correctly identify glacier margins covered by snow on air or satellite photo images. Therefore, such assessment of glacier changes remains ambiguous (Finaev 2009; Schetinnikov 1998). Nevertheless, glacier recession will strongly affect the irrigated agriculture, which consumes almost 84% of annually available surface water resources in Central Asia (Shiene and Mirzabaev 2009).

28.3.2 Lakes of the Pamir Mountains

28.3.2.1 Geophysical Characteristics

According to an inventory prepared by Mergili et al. (2013) and based on remotely sensed data, there are 1642 lakes in the Tajik Pamir. As far as the number of lakes is concerned, 73.3% of them developed above 4000 m a.s.l. However, these lakes are rather small and constitute only 19.4% of the total area of lakes in the Tajik Pamir. The largest lakes formed mostly in the areas between 3000 and 4000 m a.s.l. (Mergili et al. 2013).

The lakes can be classified into three general categories: (1) erosion lakes, defined as impounded by rock barriers or embedded in postglacial undulating depressions, at some distance from the recent glaciers; (2) block or debris-dammed lakes, impounded by dams formed by coarse blocks and debris, originated from terminal moraines, landslide deposits, talus or debris cones; (3) glacial lakes, developed on the surface of the glacier itself (supraglacial) or impounded by former moraines downstream of steep glaciers (proglacial) (Gardelle et al. 2011; Mergili et al. 2013).

Erosion lakes (885 in the Tajik Pamir) are located predominantly in the southern part of Pamir. However, the biggest lake, Kara Kul (405 km^2), developed in the northeastern part of the mountains. The Kara Kul basin is one of the most prominent features of the Tajik Pamir and its origin is still discussed. In the 90s, with the advances in satellite images and their analysis, scientists proposed that the basin is an impact structure. However, more recent studies conclude that the basin is in fact a graben, and is currently experiencing NW–SE directed transtensional deformation

(Gurov et al. 1993; Chicarro et al. 2003; Amidon and Hynek 2010). Nevertheless, Kara Kul falls into the broad category of erosion lakes provided by Mergili (2013). According to analysis of satellite images, 6.6 % of erosion lakes in the Tajik Pamir were confirmed as growing in the period of 1968–2009 and 4.6 % of erosion lakes as shrinking (Mergili et al. 2013).

Block and debris-dammed lakes are quite common in the Central Asian Mountains because of their high seismic activity. There are 105 such lakes located in the Tajik Pamir, mostly in its central part, with the best known example of Sarez Lake, which was formed during a major earthquake in 1911. Analysis of satellite images showed that in the period of 1968–2009, 5.7 % of dammed lakes were growing and 2.9 % shrinking. Yet, due to a small sample size, these results are of low statistical importance (Mergili et al. 2013).

A majority of glacial lakes (652 in the Tajik Pamir) are located in the comparatively high ranges of the southwestern and extensively glacierized western parts of Pamir. Glacial lakes dominate in the zone of recent glaciers and fresh moraines above 4500 m a.s.l., with the highest lake identified above 5100 m a.s.l. It is estimated that 95.6 % of all glacial lakes are located in the areas with at least sporadic permafrost (Mergili et al. 2012). As such, glacial lakes can be viewed as early indicators of climate warming, reflecting the state of glaciers and permafrost as their sources of water.

According to the analysis of satellite images, there is a highly significant increase in the glacial lakes in the period of 1968–2009. While the lakes of other types remained mostly constant in size, 41 % of glacial lakes were confirmed as growing, with only 2 % confirmed as shrinking. During the study period, the number of growing glacial lakes in the southwestern part of Pamir has decreased, whereas in the central and northern parts of Pamir it has increased, reflecting trends in glacier dynamics. It is hypothesized that the process of glacier retreat has started earlier in the southwestern part of Pamir than in its central and northern parts, which are more humid and therefore, more favorable for glacier accumulation processes (Mergili et al. 2012). A parallel situation was described for the Hindu Kush Himalaya range by Gardelle et al. (2011). From a geodynamic point of view, changes of glacial lakes are a part of the transition from a glacial system to a paraglacial system that is occurring now in the glacierized areas of the world (Ballantyne and Benn 1996; Salerno et al. 2014). It is important to denote that growing glacial lakes may pose a risk of Glacial Lake Outburst Floods (GLOFs) to the downstream communities (ICIMOD 2011).

28.3.2.2 Hydrochemical Characteristics

Lakes of the Pamir Mountains are fed by very differentiated sources, including glaciers, rivers (of glacier origin), melt water, groundwater, geothermal springs, and sparse precipitation. Water coming to the lakes is usually highly mineralized, which combined with the high evaporation rate characteristic for this region, causes

Table 28.3 General characteristics of the chosen lakes in the Pamir. Area of the lakes given after Pachajanov et al. 2002

Lake	Altitude [m a.s.l.]	Area [km^2]	pH	Temperature (summer)	EC [mS/cm]	SAL [mg/l]	DO [mg/l]	Author
Karakul	3928	380	9.2	9.7–13.2	10.3	7500	6.8–7.6	Mischke et al. 2010
Sarez	3261	79.4	8.8	×	×	261–1494	×	Achorov 2006
Zorkul	4125	41.7	6.2–9.4	9.4–12.9	×	183.3	×	Achorov 2006
Yashlikul	3734	36.1	7.8–8.4	8.0–9.5	×	147–341.2	4.83–12.88	Achorov 2006
	×	×	8.68–8.73	12.6–13.0	0.25	120	6.07–6.5	our data
Sassykul	3825	8.92	10	10.3		141,000		Achorov 2006
	×	×	10	13.9–15.9	84.4	59,000	2.14–8.45	our data
Rangkul	3784	7.8		16.5		463		Achorov 2006
	×	×	7.81–9.54	11.9–12.1	0.07–1.3	30–650	5.85–6.03	our data
Bulunkul	3767	3.5	8.4	11.8		114	5.02–8.96	Achorov 2006
	×	×	8.53–10.76	11.5–15.4	0.17–0.37	80–180	4.37–6.75	our data

increased salinity of the water bodies. The majority of the Pamir lakes belongs to a Ca-HCO_3-SO_4 type and contains approximately 0.20 g/dm^3 of the total dissolved solids (Volkova 1998). While lakes located in open basins remain fresh or subsaline (e.g. Yashilkul, Zorkul, Bulunkul), salinity of endorheic lakes, characterized by no outflow and weak groundwater circulation increases, reaching even hypersaline level (e.g. Sasykkul, Chukurul, Tuzkul). With the salinity of lakes, their pH increases, which in hypersaline water bodies is about 9–10 (Volkova 1998; Pachajanov et al. 2002). General characteristics of chosen Pamir lakes are shown in Table 28.3.

The chemical composition of water depends mostly on geological characteristics of the lake catchment and reflects intensity of mineral leaching, governed mainly by climatic factors. In the case that lakes are fed by geothermal or mineral springs (e.g., lakes in the Sasykkul depression), they are characterized by high concentrations of trace elements, including rare metals, in water, and sediments. Volkova (1998) detected among others high concentrations of boron (up to 30 mg/dm^3) and lithium (up to 7.8 mg/dm^3) in the waters of Sasykkul depression lakes. These elements are regarded as markers of geothermal water input to the lake (Tan et al. 2012).

Since the organic matter content in the Pamir lakes is usually low, ions of trace elements form inorganic complexes, mostly chloride, carbonate, and hydroxide. Data presented by Volkova (1998) shows that concentrations of trace elements in the water of the lakes in the Sasykkul depression are 1–3 orders of magnitude greater than in oceanic and fresh lake waters. Accumulation of trace elements in lakes is intensified also by high rate of evaporation, typical for arid regions. As a result, both water and bottom sediments of such lakes can be treated as potential sources for rare metals extraction (Volkova 1998; Pachajanov et al. 2002; Tan et al. 2012).

28.3.2.3 Impact of Climate Warming

Being directly or indirectly dependent on glacier water, high mountain lakes and ponds are especially vulnerable to climate change and can act as its early indicators. As it was demonstrated by recent observations and mesocosm experiments, climate warming results in mobilization of ions from the catchment, increase in alkalinity, and rise in amounts of phosphorus in lake waters (Koinig et al. 1998; Yan et al. 1996; McKee et al. 2003; Feuchtmayr et al. 2009; Nickus et al. 2010; Moss 2012). With increasing temperature, weathering intensifies, providing additional input of major ions into the lakes. Advancing glacier melting releases high amounts of trace elements, while droughts reduce input of darkly-colored organic matter into the lakes. This process results in reduction of absorption of UV-B radiation, which is potentially damaging for living organisms (Koinig et al. 1998; Yan et al. 1996; McKee et al. 2003; Feuchtmayr et al. 2009; Nickus et al. 2010; Moss 2012). According to McKee's (2003) and Feuchtmayr's (2009) experiments, warming has no effects on nitrate and ammonium concentrations in lake water. However, it causes significant increase in soluble reactive and total phosphorus concentrations, conductivity, and alkalinity (decreasing pH) (McKee et al. 2003; Feuchtmayr et al. 2009; Moss 2012). These changes may lead to disproportional development of the Cyanobacteria population in high mountain lakes, forming floating mats, which in turn may create dark, deoxygenated conditions under them (Kosten et al. 2012; Moss 2012). In the case that there are organic sediments in the lake, warming increases their respiration rate and mobilizes carbon sequestrated in them (Gudasz et al. 2010; Moss 2012).

28.4 Biological Diversity

28.4.1 Plant Diversity

In the Eastern Pamir about 800 plant species were noted (634 according to Ikonnikov, 1963), and in the Western Pamir about 2000 (1567 according to Ikonnikov 1979).

The percentage of endemic species in the total flora of the given elevation belt in the Eastern Pamir is 9.8 % in the subalpine and 4.6 % in the alpine belt. In contrast, endemics in the Western Pamir are 3.4 % and 1.7 % respectively. The endemism percentage is relatively low compared to other mountain ranges, i.e., in the Hindukush, endemics are about 20 % of subalpine flora and over 30 % in the Central Caucasus (Agakhanjanz and Breckle 1995). The vegetation of the Pamir high mountain zone consists predominantly of persistent herbs and small shrubs. The altitudinal range of plant communities is obviously dependent on climate conditions, but the availability of water is a factor of no lesser importance. For this reason, different types of vegetation create specific patchworks on slopes and penetrate each other. That is why it is difficult to describe discrete belts of vegetation. In Russian literature devoted to the analysis of the Pamir flora and vegetation, authors divide the high mountain zone into three belts distinguishable on the basis of climate conditions. (Stanjukovitsch 1949):

- subalpine (low high mountain belt)—from 3600 (3500) to 4100 (4200) m a.s.l.
- alpine zone (middle high mountain belt)—from 4100 (4200) to 4700 (4800) m a.s.l.
- nival zone (upper high mountain belt)—above 4700 (4800) m a.s.l.

The subalpine belt is characterized by an average period of 30 (26–72) days without frost, which occurs in the summer months of July and August. At that time, the average temperature ranges from 5.7 to 10.5 °C. Annual precipitation ranges from 60 to 125 mm/y (Stanjukovitsh 1949; Ikonnikov 1963). Most of it occurs in the summer. In the lower part of the subalpine belt, precipitation is very small. The diurnal amplitude of temperature at ground level reaches 50 °C. Air humidity drops below 20 % during the day.

In the alpine zone, there are no periods without frost. During the growing season, monthly average temperatures are 3–5 °C. Precipitation only in the form of snow, reaches on average 350 mm. Vegetation occurs in the subalpine and alpine belts. The nival zone border is simultaneously the border of the occurrence of vascular plants. (Fig. 28.3)

28.4.2 Main Vegetation Types of the Pamir High Mountain Belt

Because of little precipitation, a harsh climate, and high elevation, xerophytic and kriofilous vegetation dominates in the Pamir Mountains (Table 28.4). Most plant communities have small projective cover and small species richness. Teresken and wormwood deserts dominate in the lower (subalpine) belt. At times, near lakes, rivers, springs, and at outflows of groundwater, steppes dominated by grasses occur. Teresken and wormwood deserts disappear in the middle high mountain belt, along elevation gradients and cushion plant associations become the predominant form of vegetation.

Fig. 28.3 Vegetation of the Pamir Mountains. **a** Teresken desert; **b** cushion plant from genus Acantholimon; **c** salt marsh; **d** mountain meadow; **e** willow bushes; **f** fen

28.4.2.1 Tugai: Forests of the Flood Plains

Tugai are the shrub communities on hydrogenic habitats that occur along riversides and around springs from the lower part of the subalpine belt up to 3500 m a.s.l. The most dominant species in the lower part of their altitude range are *Betula pamirica*, other *Betula* species, and *Populus pamirica*. On the slopes of big river valleys (e.g., valley of the Panj River) numerous stands of prickly shrubs with *Hippophae rhamnoides* and *Beberis integerrima* are preserved. In the upper part of the subalpine zone most frequent are associations of willow bushes with *Salix turanica, S. schugnanica, S. wilhelmsiana*, and others. In the Western Pamir, dwarf shrubs of *Salix schugnanica* occur on river floodplains up to 3700 m a.s.l. and on the border between the Western and Central Pamir up to 3900 m a.s.l. According to historical archives, willow tugais occupied much bigger areas in the past. In the beginning of the twentieth century, most of them were cut. Areas obtained in this way were used for pasture (Agakhanjanz 1966).

Table 28.4 Area of landcover and vegetation types in the Eastern Pamir. (from Breckle and Wucherer 2005, modified)

Land Formation/Vegetation type	Elevation (m)	Area (ha)	Percentage
Mountain deserts		73,210	33.20
mainly *Ceratoides*	3500–4200	62,820	28.49
mainly wormwood desert	3500–4600	10,400	4.71
Mountain steppes, mainly *Stipa*	3500–4000	21,000	9.52
Cushion plants associations	3500–4100	950	0.44
Other ecosystems including riverbanks, floodplains, tugai	3500–4400	11,120	5.04
Bare open scree, rocks, glaciers, including kryophytes	(3550)–7000	114,220	51.80
Total		220,500	100

28.4.2.2 Salt Marsh Vegetation

Salt marshes vegetation consists of plant communities with small species richness. It occupies drying-up shores of some Pamir lakes with a high level of salinity, such as Bulunkul, Sasykkul, Shorkul, and others. Phytocenoses located close to the lakesides are usually dominated by grasses like *Puccinellia pamirica, P. hackeliana, Carex stenophylloides* sedge or *Blysmus rufus*. Other communities which occupy larger areas located on drier saline soil consist of halophytes such as *Glaux maritima, Blysmus compressus, Potentilla dealbata, Triglochin maritima*, and other species of genera *Saussurea, Kochia*.

28.4.2.3 Kobresia Meadows

Meadows are usually dominated by one species of genus *Kobresia,* such as *Kobresia pamiroalaica, Kobresia stenocarpa*, or *Kobresia capiliformis*, with a significant, ongoing share of the dicotyledonous herbs *Primula pamirica, Potentilla anserina,* and *Gentiana leucomelana*. They occur in areas located in the upper parts of floodplain terraces of rivers and lakes, bordering steppes and teresken deserts. A dense vegetation cover, significant share of grasses and legumes of genus *Astragalus* (increases protein abundance), and a dry substrate are all favorable for yak and cow grazing (Ikonnikov 1967).

28.4.2.4 Fens

Fen vegetation develops in places with high groundwater levels (lakesides, riversides, springs), yet usually not flooded, as in the case of tall sedge vegetation. In Russian literature this type of vegetation is included into meadows as "boloto" (Ikonnikov 1963). However, it differs from typical meadow communities with presence of organic soil, high and constant soil moisture and existence of moss cover. This type of vegetation is located in a mosaic of meadow and tall sedge patches. Although this type of vegetation is peat-forming, peat deposits are usually shallow and several centimeters thick; sometimes peat is almost absent. Species composition depends mainly on water salinity. In spring areas, fed with nonsaline water, brown moss cover may be dense, reaching almost 100 %. Dominant moss species belong to *Brium* and *Drepanocladus* genera. With increasing water salinity, mosses are less frequent and eventually become absent. Dominant higher plant species are monocotyledons. Typical plant species dominants are *Carex orbicularis, Carex microglochin, Carex melanantha,* and *Blysmus rufus*; other typical plants are *Eleocharis quinqueflora, Triglochin palustre, Stellaria brachypetala, Saxifraga hirculus,* and *Pedicularis rhinanthoides. Kobresia* species are absent or occur with low coverage. Fen vegetation is commonly used as pastures.

28.4.2.5 Fens with Tall Sedges Vegetation

Fens with high sedges belong to the vegetation zone occurring on flat lake shores or the banks of slow flowing rivers and streams with a lower salinity level. The main environmental factor that enables their existence is always permanent water stagnation. They are characterized by a strong domination of one sedge species, e.g., *Carex orbicularis*, *Carex pamiriensis*, *Carex pycnostachia* or *Hippuris vulgaris* and *Blysmus rufus*. High sedges communities are often used as hay meadows. The density of tall sedge populations is usually very high. They achieve a cover of 70–100 % and a height of 30–70 cm and give the biggest yield among meadow phytocoenoses, but with low feed value.

28.4.2.6 Deserts with Predominantly Dwarf Shrub

In the subalpine belt, river valleys and slopes at altitudes from 3600 to 4500 m a.s.l. are occupied by desert vegetation dominated mostly by dwarf shrubs *Eurotia ceratoides* (*Krasheninnikovia ceratoides*) with cooccurrence of other species like *Artemisia rhodonta*, *A. leucotricha*, *Xylanthemum pamiricum*, and *Ajania tibetica*. It is characterized by small species richness (2–7 species per relevé) and small vegetation cover (5–12 %). Less frequently, deserts are covered with communities dominated by species belonging to the genus *Artemisia* (*A. rhodonta*, *A. leucotricha*, *A. kuschakeviczii*). They have bigger species richness and cover (up to 20 %). Desert vegetation occurs on stony and gravelly substrate in places without water supply for most of the year. It is traditionally used by the local population as a source of firewood and as extensive pastures for small ruminants and donkeys.

28.4.2.7 Steppes

Steppes occur on valley bottoms and slight slopes. They occupy small areas scattered throughout the Pamir Mountains on sand and gravel soils at an elevation from 3700 to 4200 m a.s.l. This type of vegetation is characterized by domination of grasses like *Stipa (Stipa galerosa, S. orientalis), Festuca sulcata, Poa litvinoviana, Hordeum turkestanicum, Ptilagrostis subsessiliflora* or herbs like *Christolea pamirica* and *Christolea crassifolia*. Patches of plant communities with domination of Festuca sulcata are usually the most numerous. The vegetation cover ranges between 25 and 50 %. Most of the investigated communities consisted of 12–18 plant species (Stanjukovitsh 1949; Agakhanjanz 1966)

28.4.2.8 Cushion Plant Associations

The middle zone of the alpine belt is dominated by cushion vegetation consisting of mountain xerophytes. Its distribution begins from 3800 m a.s.l., yet this vegetation type dominates only above the zone of dwarf shrub vegetation. In this harsh high mountain environment, due to the morphological adaptations typical for such conditions (e.g., miniaturization and oligomerization of shoots), dominant plant species resemble cushions. The species composition of these plant associations is very diverse. Most frequently, in different regions of the Pamir Mountains, their species composition includes *Acantholimon diapensioides*, *Sibbaldia tetrandra, Oxytropis immersa, Gypsophila cephalotes, Chesneja crassipes*, *Onobrychis echidana,* and some species from genera *Oxytropis, Ephedra, Astragalus, Tragacantha,* and *Aegacantha*.

28.4.3 Fungal Diversity

As far as fungi are concerned, extreme environments (e.g., high mountains, hot and cold deserts, or polar regions) were attentively investigated only recently, with the advent of modern molecular and statistical techniques. Such environments pose an interesting problem for researchers, since they harbor communities of highly specialized organisms adapted to harsh conditions. The composition of these communities may be simple, yet species interactions are nevertheless complex.

The cryptoendolithic communities of fungi, algae, and bacteria in dry valleys of mainland Antarctica are probably the most spectacular example (e.g., Selbmann et al. 2005; de la Torre et al. 2003). Unfortunately, while the lichen diversity is relatively well recognized, studies on nonlichenized fungal communities of the Pamir Mountains are scarce and unsatisfactory.

Even though some extensive inventories of nonlichenized fungi and lichens of Tajikistan (Korbonskaya 1990; Kudratov and Mayrhofer 2002; Feuerer 2013) exist, they comprise, majorly, old herbarium data compiled from Soviet works, usually collected in a rather nonsystematic way. According to these sources, there are 2233 species of nonlichenized fungi and 524 species of lichenized and lichenicolous fungi recorded from Tajikistan. It has to be noted that Pamir is virtually absent from Western mycological literature. In the GBIF database, there are only 88 records of fungi from Tajikistan, but only 3 from Pamir, and all those 88 records are lichens (www.gbif.org, accessed 09 Oct 2014). Searching in the MycoBank database (www.mycobank.org, accessed 09 Oct 2014) for fungal species with "pamir" in the epithet brings on 13 valid species and formae, of which eight are nonlichenized fungi. On the other hand, GenBank database (www.ncbi.nlm.nih.gov, accessed 09 Oct 2014) resources from the Pamir Mountains are extremely scarce, comprising only nucleotide sequences of a yeast *Cryptococcus aerius* originating from research from 1971 and basidiomycetous yeast Tausonia pamirica described from soil.

To date, the only recent research on nonlichenized fungi from Tajikistan is that by Zubek et al. (2011) concerning fungal root endophytes. The authors investigated 16 species of endemic plants occurring in the Pamir Alay range, and screened them for the presence of dark septate endophytes (DSE) and arbuscular mycorrhizal (AM) colonization. Obtained results indicated high incidence of colonization by DSE (10/16 plant species) and AM (15/16 plant species). Older research focused mostly on the quantitative (i.e., expressed as the Colony Forming Units, CFUs, without further identification) differences in microbial communities between soil types in the Pamir Mountains (e.g., Khudjakova and Babjeva 1970). An interesting attempt was done by Babjeva, Rjeshjetova and Vovk (1970), who investigated microbial communities in thalli of 14 epilithic lichen species. The authors however applied only culturing methods and again focused predominantly on bacteria and actinomycetes, without direct screening of the lichen thalli for the presence of any nonlichenized fungi. They stated that the thalli were almost free from fungi, with the exception of *Rhodotorula mucijaginosa*, *Rhodotorula* sp., and *Cryptococcus neoformans*. These results are interesting in view of the recent work by Selbmann et al. (2013), who considered epilithic lichens as a novel microniche for black meristematic fungi in mainland Antarctica.

Lack of basic research prevents from giving any statements about possible adverse effects of global climate change and growing anthropopressure on fungal communities. Although there is a Red Data Book of fungi, plants, and animals of Tajikistan (1988), there are only four species of fungi included and the list is in urgent need of revision; none of the fungal entries is from the Pamir Mountains (The Red Data Book of Tajikistan 1988). Zubek et al. (2011) mention endophytic and mycorrhizal fungi in the context of endemic plant protection, but also state that further research is needed.

It can only be speculated that desertification and salinization, already posing a great problem in Central Asia (Saiko and Zonn 2000), together with overgrazing, will affect all fungal communities occurring in fragile mire ecosystems around lakes and along river valleys. However, how detrimental these effects will be and how these disturbances will affect high mountain and desert fungi is also unknown.

28.4.4 Animal Diversity

With 13,150 recorded species, including as much as 800 considered endemic, Tajikistan can be considered as one of the world's hotspots for faunal biodiversity (National Strategy and Action Plan on Conservation and Sustainable Use of Biodiversity 2003; Squires and Safarov 2013). According to these data, only one of those endemic species represents vertebrates, namely the Buchara shrew (*Sorex buchariensis*), and the rest are invertebrates. It has to be noted, however, that according to other sources, two species of lizards, namely the Tajik Even-fingered Gecko (*Alsophylax tadjikiensis*) and the Darvaz Snake-eyed Skink (*Ablepharus darvazi*), and one species of fish, the Tajik Loach (*Nemacheilus pardalis*), are also considered endemic for Tajikistan (Checklist of the Endemic Plant and Animal Species, http://lntreasures.com/tajikistanff.html, accessed 09 Oct 2014). One of the possible reasons for such diversity and endemism of fauna is the great diversity of habitats occurring in the country and relatively high level of isolation in the mountain areas. The recent work by Navruzshoev et al. (2013), dedicated to the rare and endangered fauna and flora in the Gorno-Badakhshan region of Tajikistan (covering all the Pamir) lists 20 species of invertebrates, 3 species of reptiles, 19 species of birds, and 15 species of mammals; all of them figuring in the Red Data Book of Tajikistan or Red Data Book of the USSR.

28.4.4.1 Invertebrates

Many of the species listed by Navruzshoev et al. (2013) were recorded from warmer mountain areas of Darvaz and Rushan, including three species of the order *Mantoidea*. Mountain meadows and vegetation along stream valleys host six species of rare butterflies of the genus *Parnassius*, among them *P. autocrator* and *P. apollo*, both listed by the IUCN Red List with the category VU (vulnerable). Two interesting species of snails of the genus *Melanoides*, inhabiting hot springs in the Pamir Mountains are also included in the list. Recently, an interesting, darkly pigmented form of *Daphnia longicaudata* was discovered in the Rangkul Lake, which was proven to be the highest and southeasternmost locality for this species (Möst et al. 2013). Although the direct influence of climate change on the populations of these invertebrates requires investigation, it is obvious that by affecting the vegetation it will also have a negative effect on associated invertebrate communities. A more serious threat is posed by overgrazing by goats, sheep, cows, and yaks. Livestock directly destroys the habitat and food base of many insect species, which is additionally enhanced by the use of pesticides (Navruzshoev et al. 2013). Serious destruction of aquatic habitats in case of aquatic snails, and direct destruction of ootecas (filled with eggs) laid by mantises all caused by livestock are also mentioned, as well as poaching for private collections (Navruzshoev et al. 2013).

28.4.4.2 Reptiles

The three species of reptiles listed by Navruzshoev et al. (2013), namely skink *Asymblepharus alaicus*, Central Asian Cobra (*Naja oxiana*), and Turan Blunt-Nosed Viper (*Macrovipera lebetina turanica*), were recorded only from warm areas in the vicinity of Khorog, and in the Darvaz and Rushan, being absent from the rest of the Pamir Mountains. Poaching (for ornamental and medicinal purposes) and earthworks for the construction of highways, especially the road Khorog-Khulob, are listed as major threats there (National Strategy and Action Plan on Conservation and Sustainable Use of Biodiversity 2003; Navruzshoev et al. 2013).

28.4.4.3 Birds

High-altitude lakes in the Pamir Mountains are well known for their rich avifauna. According to the BirdLife international criteria, there are seven Important Bird and Biodiversity Areas (IBAs) in this region: the Karakul Lake and surrounding mountains, the Zorkul Nature Reserve, Ishkashim, Dzhavshangoz, the Drumkul Lake, the Bulunkul and Yashilkul Lakes and surrounding mountains, and Rangkul Valley (the Rangkul and Shorkul lakes) (www.birdlife.org, accessed 09 Oct 2014). From the work by Navruzshoev et al. (2013), 15 species are recorded by the IUCN Red List with the category LC (least concern), two, namely Himalayan Griffon (*Gyps himalayensis*) and Bearded Vulture (*Gypaetus barbatus hemachalanus*) are listed as NT (near threatened), and two, Egyptian Vulture (*Neophron percnopterus*) and Saker Falcon (*Falco cherrug milvipes*) have category EN (endangered). The main threats for many bird species in the Pamir Mountains remain habitat destruction by livestock, and pouching (also illegal trapping of live falcons for falconers from Middle East) (National Strategy and Action Plan on Conservation and Sustainable Use of Biodiversity 2003; Navruzshoev et al. 2013; Squires and Safarov 2013).

28.4.4.4 Mammals

According to the list by Navruzshoev et al. (2013) seven species of mammal are also recorded on the IUCN Red List with the category LC, including four species of bats, the Brown Bear (*Ursus arctos isabellinus*), the Turkestan Lynx (*Felis lynx isabellina*), and the Least Weasel (*Mustela nivalis pallida*). The Altai Weasel (*Mustela altai casancana*), Eurasian Otter (*Lutra lutra seistanica*), and the Argali or Marco Polo sheep (*Ovis ammon*) occurring in the Pamir Mountains, have the category NT according to the IUCN Red List. The most endangered are the species often seen as the flagship animals of the Pamir—the Urial (*Ovis orientalis*), with the category VU, the Markhor (*Capra falconeri heptneri*), and the Snow Leopard (*Uncia uncia*), both with the category EN according to the IUCN Red List. In addition, the Dhole (*Cuon alpinus*), recorded from the Eastern Pamir, is a rare species classified with the category EN. It has to be noted that the information on the population densities, dynamics, etc. of these animals is lacking and requires further study (Schaller and Kang 2008).The greatest hazards for most of those animals remain pouching, including also commercial trophy hunting, overgrazing and competition from livestock, and overexploitation of teresken (*Eurotia* spp.) by the local people—all leading to the severe shortage of food for ungulates (Schaller and Kang 2008; Michel and Muratov 2010; Navruzshoev et al. 2013). Heavy winters with high snowfall are also considered detrimental to the populations of Argali, Urial, or Siberian Ibex (*Capra sibirica*), as the animals are often isolated in areas depleted in food (Michel and Muratov 2010).

28.5 Wise Use and Threats

The Pamir area is renowned for its unique mountain ecosystems with many endemic plants and animals, and thus constitutes an important global gene pool with outstanding importance for the whole of Central Asia and beyond. Current land and water resource management practices, however, are threatening the long term preservation of this unique mountain area as a space both for human use and wilderness (Foerster et al. 2011, Pachowa et al. 2012). In the Pamir Mountains, crops depend on the availability of irrigation water, which will increase in the short term in some areas, because of the acceleration of glaciers melting, yet in other areas will continuously and gradually decrease. In a long run perspective, in all areas there will be less water available and its quality will probably be worse, resulting in numerous problems with irrigation, dryer pastures, increasing risk of overgrazing, more sheet erosion, and lack of fodder, particularly in winter. Subsequently, agricultural methods, including animal husbandry (fodder supply in winter) and rangeland management, need to adapt to changing conditions (Strategy and Action Plan for Sustainable Land Management in the High Pamir and Pamir-Alai Mountain 2011).

Especially important is modification of environmentally detrimental and unsustainable practices that have already led to severe land degradation, which is threatening the integrity and functioning of the fragile mountain ecosystems.

28.5.1 Vegetation and Climate Change

According to the literature, increasing air temperatures in the high mountains may lead to higher evapotranspiration, lower groundwater reserves and more frequent droughts, which will result in water deficiencies for plants (Beniston 2003). Thus, we may expect shift from meadow and steppes vegetation into the semi-desert type and increase in the area without vegetation. Vegetation which is directly linked to high water availability (peatland, reed bed) is especially endangered with changes in water supplies.

As far as the Pamir Mountains are concerned, with melting of glaciers, the water regime of rivers may be disturbed. Glacier recession may lead to increased water runoff in spring, with strong water runoff reduction in summer (Khromova et al. 2006). Water flow in rivers may become more unstable, being more dependent on precipitation (Hagg et al. 2006). This could lead to flooding of wetland vegetation in spring and subsequent drought in summer. Wetland plants demand constant water availability, so we can expect their disappearance as wetlands are desiccating, and replacing them with plants more tolerant to water deficit (Keddy 2010).

28.5.2 The Degradation of Pamir Vegetation, Causes, and Effects

The Pamir Mountains are sparsely populated. Industry is lacking. The main forms of anthropopression in the Pamir Mountains are livestock grazing and the use of hay meadows and dwarf shrubs as supplementary feed for livestock and as firewood. Effects of different forms of anthropopression on vegetation of the Pamir is shown in Table 28.5.

28.5.3 The Use of Dwarf Shrub Vegetation

The primary source of energy in the Pamir Mountains is animal manure. Because manure resources are limited, teresken shrubs (*Eurotia ceratoides*) are used as a supplementary source of energy. The acquisition of manure is not a problem for people living in villages (kishlaks), where most inhabitants are engaged in pastoralism. For families living in towns like Murghab or Alichur and working in administration or commerce, who have limited access to manure, teresken was the only source of energy for a long time after the dissolution of the Soviet Union. In the period from 1960 to 1992, the demand for fuel was covered by the import of coal from Siberia. In 1992, the system of provisioning Pamir with fuel stopped. The limited supply of imported fossil fuels induced an increased use of desert vegetation for firewood. Presently, dwarf shrub vegetation has almost completely disappeared in the neighborhood of bigger settlements (Kraudzun et al. 2014) (Fig. 28.4). The amount of acquired desert vegetation has obvious influence on the stability of plant

Table 28.5 Degradation of vegetation. (from Breu and Hurni 2005)

Forest	Major Degradation Forms	Degree	Major Causes
Western Pamirs	Reduction of area	High	Firewood harvesting, logging for timber, lack of regulations and control
	Reduction of vegetation density	Moderate	Firewood harvesting, browsing damage
	Decline in number of species	Low	
	Degradation of single plants	Moderate	Browsing, firewood cutting
Eastern Pamirs	Reduction of residual willow tree stands	Low	Browsing, firewood cutting
Alai Mountains	Reduction of area	High	Firewood harvesting, logging for timber, lack of regulations and control
	Reduction of vegetation density	Moderate	Firewood harvesting, browsing damage
	Decline in number of species	Moderate	
	Degradation of single plants	Moderate	Browsing, firewood cutting
Shrubs	*Major Degradation Forms*	*Degree*	*Major Causes*
Western Pamirs	Removal of vegetation cover	Moderate	Shortage of fuel, overstocking of pastures
Eastern Pamirs	Removal of vegetation cover	High	Shortage of fuel, overstocking of pastures
Alai Mountains	Removal of vegetation cover	Moderate	Shortage of fuel, overstocking of pastures
Pastures	*Major Degradation Forms*	*Degree*	*Major Causes*
Western Pamirs	Sheet and rill erosion	Moderate	Overstocking of pastures, trampling damage
	Decline in productivity	Low	Lack of nutrient input/ shortage of fuel
	Salinization on riparian areas	Moderate	Removal of tree cover and undergrowth
	Reduction of vegetation cover	Great	Overstocking, nutrient mining

Table 28.5 (continued)

Forest	Major Degradation Forms	Degree	Major Causes
Eastern Pamirs	Sheet and rill erosion	Moderate	Overstocking of pastures, trampling damage
	Decline in productivity	Low	Lack of nutrient input/ shortage of fuel
	Salinization	High	Removal of dwarf-shrub cover
Alai Mountains	Strip and ravine erosion,	Moderate	Overstocking of pastures, trampling damage
	Reduction of vegetation cover	High	Lack of nutrient input/ shortage of fuel
	Increase in volume of non-fodder plants	Moderate	Overstocking, pasture management
	Intrusion of undesirable bushes and trees	Moderate	

Fig. 28.4 Teresken harvested for firewood

populations. The way the plants are acquired is of great importance. For herdsmen living in villages, teresken is not only fuel, but also supplementary feed for livestock used during the winter. For this reason, they harvest teresken selectively. Shrubs with lower viability, which cannot give a good yield in the next growing season, are the first to be collected. Unselective acquisition on a large scale done by the inhabitants of bigger settlements results in complete destruction of the vegetation cover. The results of such practices are: (1) significant decrease in the area of desert vegetation; (2) reduction of food resources available for wild herbivores like Marco Polo sheep; (3) initiation of wind erosion causing the region's desertification.

28.5.4 Pastoralism

Despite a low population, Pamir's pastures are often overgrazed because the area of land available for hay and forage management is very small. The estimated surface of meadows and wetlands occupies 1–2 % of the Western Pamir and less than 1 % in most of the Eastern Pamir districts (Agakhanjanz 1966). Meadows and fens occur only on floodplain terraces of rivers, streams, lakes, and outflows of ground water. The length of the growing season and species structure differ depending on the elevation. According to the literature, almost all types of vegetation are considered as sources of forage. They differ in terms of yield, the quality of forage, and the abilities of use by livestock.

Pastures located along rivers and lakes with domination of *Carex* spp., *Kobresia* spp. and grasses, produce crops from 0.6–5.3 t/ha of green mass (Agakhanjanz 1966; Ladygina and Litvinova 1974; Vanselov 2011). Teresken deserts yield only 0.07–0.5 t/ha green mass. Wormwood deserts produce from 0.6–1.0 t/ha green mass. The vegetation of meadows brings the highest yields, of higher forage quality and energetic efficiency than steppe and desert dwarf shrubs vegetation (Vanselov 2011). Moreover, only a small part of dwarf shrubs biomass could be grazed by big ruminants such as cows and yaks. For the reasons mentioned above, yaks and cows graze in meadows, which is shown on the Fig. 28.5. Much larger areas with desert vegetation are often grazed upon by small ruminants, like goats or sheep that graze "on the run," so the damage to the desert vegetation is much smaller. Cattle grazing on such a limited area of meadows contributes significantly to a decrease in biodiversity (Breckle and Wucherer 2005).

The main effects of overgrazing are the extinction of some plant species and soil erosion caused by heavy livestock. Kobresia and sedge pastures are unevenly degraded. In accordance with the local tradition of cattle grazing, there are summer and winter pastures in Pamir and other mountains of Middle Asia. Summer pastures are situated higher, in the upper part of the subalpine and alpine belts, even up to 4500 m a.s.l. They are used by yaks during a short growing season in July and August. This is the time when plants grow and reach the phenological stages of flowering and fruiting. However, most of them cannot reproduce because of grazing. Winter pastures are located near villages, around lakes in lower parts of valleys. During summer, they stay free of grazing, and plant species can go through the whole life cycle. In the second half of August, they are partially used as hay meadows and then as winter pastures. Because of the described transhumance, summer pastures located at a greater distance from settlements are often much more degraded than the winter ones (Khan and Alam 2009).

28.5.5 Endangered Plant Species

Some plant species in the Pamir Mountains are engendered with extinction because of natural causes, like small population size or limited distribution (i.e. *Saussurea caprifolia*). Some relict plants are not adapted to changing environmental conditions

Fig. 28.5 Yaks in the Gurund River Valley

which may hamper reproduction by seed (*Bergenia stracheyi*), or they may not be able to complete their lifecycle (*Primula flexuosa*). Most plants however are threatened by anthropogenic factors like overgrazing of pastures, collecting plants for fuel or medicinal use. (Navruzshoev et al. 2013). Mountainous plants of GBAO which are rare and under danger of extinction are listed in Table 28.6.

28.6 Closing Remarks

The Pamir's landscapes are extremely vulnerable to a wide range of human and environmentally-driven threats, including overgrazing by livestock, water diversions for agriculture, increasing human use due to the change in lifestyle of local inhabitants, and increased tourism (Environm. Indicators Central Asia 2005; BIOFOR 2011). Their stability depends solely on the condition of the Pamir glaciers, because they are fed directly (percolation) or indirectly (riverine) by glacial waters. Unfortunately, increasing temperatures (global warming) and growing anthropogenic pressure (hunting, teresken cutting, overgrazing), may result in major disturbances in proper ecosystems functioning and, therefore, may endanger their existence.

Accurate identification of possible threats and environmental changes (including anthropopression), that may occur in the Pamir Mountains, can be performed only after careful examination of the key hydrological, geochemical, and ecological drivers of their ecosystems (Safarov 2006; Tajikistan 2006; Strategy and

Table 28.6 Rare and disappearing plants of GBAO mountains (with altitudinal distribution 3000 m a.s.l and above) and main causes of threat. (from Navruzshoev et al. 2013)

Main cause of disappearing	Endangered species
Overstocking of pastures or haymaking (A)	*Astragalus badachschanicus* (A); *Carex borii* (A); *Desideria pamirica* (A, also C); *Erigeron pyramii* (A); *Geranium pamiricum* (A, also J); *Jurinea komarovii* (A); *Megacarpaea schugnanica* (A); *Puccinelia vachanica* (A); *Stipa pamirica* (A); *Viola tianschanica* (A)
Shrubs removal for firewood (B), building material (C), to get space for new pastures or fields (D)	*Alium winklerianum* (D, also A); *Juniperus schugnanica* (B, C); *Juniperus sibirica* (B); *Rhamnus minuta* (B, also A); *Sorbus tianschanica* (B)
Collecting for medicinal (E), food (F) or decorative purposes (G)	*Angelica ternata* (E,F); *Bunium badachschanicum* (F, also A); *Bunium persicum* (E, F); *Gypsophila capituliflora* (E, also A); *Nepeta glutinosa* (E); *Paeonia intermedia* (G, E, also A); *Polygonum schugnanicum* (E); *Rhodiola heterodonta* (E); *Ribes janczewskii* (E)
Other—limited geographical distribution or small population (H), relict with low adaptation to changing climate (I), anthropopression—general (J)	*Bergenia stracheyi* (I, J); *Colcichium luteum* (H, also J); *Kurdjaschevia korshinskyi* (J); *Oxytropis hedinii* (J); *Primula flexuosa* (I); *Primula kaufmanniana* (H, J); *Ranunculus jazgulemicus* (H, J); *Saussurea caprifolia* (H); *Saxifraga pulvinaria* (I); *Swertia fedtschenkoana* (J, also A)
Not known (K)	*Alajja rhomboidea* (K, sometimes E); *Alium pauli* (K); *Atraphaxis karataviensis* (K); *Bromopsis pamirica* (K); *Clematis saresica* (K); *Rhodiola coccinea* (K, sometimes E)

Action Plan 2011). Degradation in the Pamir Mountains must be regarded as a major threatening factor for water supply to the lowlands, as changes in water regimes will have a direct impact on irrigation water availability in other Central Asian countries (Uzbekistan and Turkmenistan). Already today, water availability constitutes the most critical factor for social, economic, and political stability in Central Asia. Furthermore, understanding the effects of climate change on ecosystems of the Pamir Mountains is important for implementing effective conservation strategies and assessing impacts on mountain livelihoods.

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