DEVELOPMENT AND PERSPECTIVES OF LANDSCAPE ECOLOGY

Development and Perspectives of Landscape Ecology

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We are looking forward to discussing the approaches to landscape ecology described here with the international scientific community.

The editors
April 2002

Preface

Development and status of landscape ecology – subject of this book

During the last decades, landscape ecology has developed tremendously. It concerns both the theoretical basis and practical application. The roots of landscape ecology are geography and biology. The term "landscape ecology" was first coined by the German scientist Carl Troll in 1939. Once, the development center of landscape ecology was in Central Europe. Recently, also other parts of the world became powerful centers of landscape ecology, especially Northern America. American approaches partly differ essentially from the European, because they are focused esp. on biogeography and population dynamics. In Europe, however, the geographical roots of landscape ecology play a major role. Landscape is defined as a complex of abiotic, biotic and human components. Mainly due to linguistic barriers, the international discussion does not take notice of approaches and experiences from non-anglophone countries in a sufficient manner. Therefore this book considers more the German and European views on landscape ecology than the books which were published before. It tries to bridge the gaps between theory and practice of landscape ecology, as well between the German/European and American approaches.

The book gives a fundamental representation of landscape ecology, which proves to be a young, but an interesting and very important transdisciplinary science for the solution of environmental problems. Both the theoretical basis and practical application of landscape ecology are considered. A great value is attached to describe approaches and experiences from Germany and Central Europe, and to discuss them in an international context.

This book is addressed to landscape planners, landscape managers, landscape conservationists and landscape architectures, to biologists and geographers, to colleges, universities, authorities and to the general public being interested in ecological issues. Among the themes are e.g. the roots and the position of landscape ecology, problems of scale and dimension, landscape analysis, diagnosis, potentials, evaluation, change, prognosis, landscape complexes, landscape functions, landscape boundaries, tools like remote sensing and information systems, landscape mapping, landscape monitoring, landscape planning, and nature conservation.

Present status of Landscape Ecology in Germany: Important centers and major themes

Due to the different roots of landscape ecology and due to the distinctive trend to specialization, landscape ecology is practiced now in a wide field of basic as well as applied research. Since many decades single factors and structures of agricultural, forest and lacustrine ecosystems have been investigated at different research institutes. Below a selection of landscape related research groups and institutions with their thematic focus is given.

Center for Environmental Research Leipzig-Halle (UFZ; http://www.ufz.de)
Established in response to the heavily contaminated landscapes in Central Germany, the UFZ is now a recognized center of expertise on the clean-up and renaturation of polluted landscapes, as well as the preservation of landscapes close to nature - and not just in central Germany. Hence the UFZ will continue to address not purely technical, environmentally relevant measures, but instead place emphasis on scientific themes which bear relevance to ecological and sociological concerns, as well as economics and environmental law.

Center for Agricultural Landscape and Land Use Research Müncheberg (ZALF; http://www.zalf.de)
The primary scientific objective of the ZALF is to analyze, evaluate and predict processes (including their interactions) in agricultural landscapes of the Northeastern German lowlands. Based on the knowledge of functional relationships within ecosystems, concepts for the use, organization and rehabilitation of landscapes are worked out.

Ecology Center of the Kiel University (ÖZK, http://www.ecology.uni-kiel.de/)
Primarily the ÖZK realizes integrative tasks in the field of basic ecological research and in the field of applied environmental research. The Ecology Center performs a tight network between different ecological disciplines in research and education. The cooperation with other universities, research

centres as well as economic enterprises and administration plays also an important role.

Forest Ecosystems Research Center Göttingen (FZW; http://www.gwdg.de/~fzw/index.htm)
The Forest Ecosystems Research carries out research into structural dynamics and element recycling processes in sylvan ecosystems as well as into the adaptability of forests in the face of environmental change. This includes study of the interaction between the ecosystems and their environment and the new types of forest damage. Last but not least, these investigations also lead to an appraisal of commercial feasibility.

Bayreuth Institute for Terrestrial Ecosystem Research (BITÖK; http://www.bitoek.uni-bayreuth.de)
With an interdisciplinary and integrated research program BITÖK is focused on the quantification of matter fluxes between the different ecosystem parts as well as between ecosystems and their environment.

National Research Center for Environment and Health Neuherberg (GSF; http://www.gsf.de)
The task of GSF is the performance of research to ensure human health and a healthy environment. They carry out investigations into the complex systems supporting life at the reactive interface between environmental influences and genetic predisposition. Their objective is the identification of risks to human health and of those threatening the ecological balance, the evaluation of the limits to the burden which we can place upon our environment, and the creation of concepts to help us to avoid long-term damage to this vital resource.

Research Association Agricultural Ecosystems Munich (FAM; http://fam.weihenstephan.de/)
FAM aims at a the long term investigation of the ecological effects of two different management systems within a landscape. Thereby ways of land management unifying economic land use with maintenance and reestablishment of natural living basics within agricultural landscapes should be pointed out.

Saxon Academy of Sciences, Working group on Natural Balance and Regional Characteristics (http://www.ag-naturhaushalt.de)
This working group deals with long term investigation of landscape changes. The group develops and tests different registration and assessment methods to specify and predict status, functioning, carrying capacity and resilience of landscapes in different dimensions. The focus is also on the analysis, evaluation and monitoring of human influences on structures and functions of land-

scape. Changes of landscape performances are especially taken into consideration by means of indicators, landscape functions and natural potentials.

There is also a new tradition in educating landscape ecology as well as geoecology at German universities since more than ten years. Until this time landscape ecology has been taught at universities – but in most cases as a part of physical geography or seldom as a part of biology. But due to the complex environmental and societal problems that became obviously within the last decades, a great request for "specialists for the whole" has been pronounced. The following table gives an overview:

Study course	University
Landscape Ecology	Greifswald (http://www.uni-greifswald.de/~alg-stud/sg/fachbesc/laoek.html) Münster (http://www.uni-muenster.de/Rektorat/studium/stud-lok.htm) Oldenburg (http://www.uni-oldenburg.de/biologie/studium/loek.htm)
Geoecology	Bayreuth (http://www.geo.uni-bayreuth.de/fachgruppe/geooek/) Braunschweig (http://www.tu-bs.de/institute/igg/) Karlsruhe (http://www.bio-geo.uni-karlsruhe.de/ifgg1/main.htm) Tübingen (http://www.uni-tuebingen.de/geooeko/) Potsdam (http://www.uni-potsdam.de/u/Geooekologie/index.htm) Freiberg (http://www.ioez.tu-freiberg.de/geo/index.html)

Furthermore, a lot of chairs/professorships on landscape ecology are existing at traditional universities as well as at universities of applied sciences too.

Traditions of IALE in Germany

There is also a long tradition in German collaboration within the International Association for Landscape Ecology (IALE). Lots of Germans participated at the VIth International Symposium on Problems of Landscape Ecological Research (October 21-26, 1982) in Piešťany/CSSR where the International Association for Landscape Ecology (IALE) has been established. The establishment of IALE just in the CSSR expressed recognition not only to the Czechoslovak science but also to landscape ecological research in the East European Region too which laid foundations of the development of international cooperation in this direction. Extensive possibilities of mutual communication of landscape ecologists at the international level have been created. Unfortunately a lot of endeavors from East Germany – the former German Democratic Republic - to active cooperation within IALE remained unavailingly – especially with respect to Western Regions. It was confined to contacts between selected sections e.g. in Roskilde/DK. So there was a specific situation in Germany: There were two separate regional sections in Germany: Karl Friedrich Schreiber (Münster) established a regional section in Western Germany and organized among other things the International IALE conference "Connectivity in Landscape Ecology" in Münster July 1987 whereas the IALE activities in the former GDR remained more or less informal. The situation changed obviously after 1990. A lot of contacts had been revived between single persons as well as between research groups and organizations – first within the formerly separated parts of Germany and afterwards between (Eastern) Germany and the other countries. Up to 1998 there was no real German IALE Section. In the IALE directory compiled by Rob Jongman in December 1997 29 German members are registered (10 of them coming from the former GDR). In spring 1998 there was an initiative by Günther Schönfelder to (re-)establish a German Regional IALE Section. This initiative has been supported by Jesper Brandt and Rob Jongman who participated in this meeting in Leipzig as representatives of the international organization. The working principles for the re-establishment of IALE-D were adopted at the foundation meeting in May 1999 in Basel. Meanwhile IALE-D has over 100 members and can review three years of active work on the national as well on the international level. The first annual IALE-D meeting was organized by Roman Lenz in Nürtingen 2000 and has been titled "The Future of the European Cultural Landscapes". Michael Kleyer arranged the meeting in 2001 in Oldenburg focused on the theme "Landscape as an Habitat". And the meeting in 2002 to be held in Dresden will attend to the relationships between landscape science and landscape (planning) practice. Representatives of German landscape ecology have all played an active role in international congresses too (e.g. INTECOL congress 1998 Florence, IT; IALE World Congresses 1991 Ottawa, Canada, 1995 Toulouse, France and 1999 Snowmass Village, USA; European IALE congress 2001 Stockholm, S/Tartu, EE). They treat essential parts in international research projects too.

Foreword by Zev Naveh

My first acquaintance with landscape ecology in Germany reached back to 1968, thanks to a visit of the late Heinz Ellenberg in Göttingen. He introduced me to two of his former students who have become meantime leading landscape ecologists: Wolfgang Haber from the Agriculture School at Weihenstephan of the Technical University of München (Munich), and Karl-Friedrich Schreiber from the Department of Geography at the University of Münster. H. Ellenberg was undoubtedly at that time the most influential German ecologist who released German phytosociology from its fixation on plant species composition and on deterministic succession-to climax concept. He developed the methodology of ecological indicators and was one of the first German ecologists realizing the active and many times positive role of humans in shaping their cultural landscapes. He also introduced the ecosystem concept into Germany with humans as integral parts of it, and initiated the first multidisciplinary ecosystem research project at the Solling forest. No wonder that as a forward-looking, holistic geobotanist and ecologist, he recognized very early the great importance of landscape ecology and paved the road for his students to join forces with geographers, landscape – planners and managers, laying the foundations for the new discipline of landscape ecology in Germany and Central Europe.

Already then I was impressed by the broad scope of German landscape ecology, being taught, studied and practiced in a great variety of academic and professional institutes. These dealt in one way or the other with "Landschaftspflege" (landscape care) which was at that time a popular term for all phases of landscape planning, design, management, conservation and restoration. I could therefore very soon recognize the unique value of landscape ecology as a transdisciplinary science on its own rights, and not just as an emerging sub-discipline of ecology and/or geography. Since then several other synthetic and transdisciplinary environmental "eco-sciences" have emerged, such as ecological economy, ecological sociology, eco-psychology But German landscape ecology was most probably the first environmentally oriented meta-discipline, transcending beyond the narrow borders of the natural sciences. This is very well reflected in the contents of this important anthology.

In recent years German landscape ecology has made great strides. It has stretched its wing farther into many more diverse academic and professional institutes and has both deepened and broadened its theoretical premises and advanced its methodology, in line with the great progress achieved in the sciences of complexity and computerized information. Many of these achievements are presented in a rather comprehensive and systematic way in this volume, and its editors, Uta Steinhardt and Olaf Bastian can be complimented for their efforts to make them available in this first, well organized and comprehensive English compilation. It presents chiefly the contributions of the "second generation" of German landscape ecologists, building on the sound foundations of the "fathers" of landscape ecology in the former West and East Germany and in Switzerland.

Judging from its content, it is evident that the majority of the active institutes mentioned and most of the contributors have a geographical background. One reason for this could be the fact that not all of the younger generation of ecologists followed the example of Ellenberg, encouraging their students to get into the field of landscape ecology, because it was regarded by them only as a second grade "applied science". At least this was the reason given by one of the most prominent German ecologists and the editor of the German Ecological Series of Springer for rejecting the publication of a German version of the English Springer book on landscape ecology (Naveh and Lieberman 1984), enriched with a special chapter by W. Haber.

Also in this book landscape ecology is regarded sometimes as "an applied science". This unfortunate distinction between higher-level, more respectable "basic sciences" and second grade "applied sciences" has lost much of its credibility. In view of the serious threats for the future of organic life on Earth, which were first revealed almost forty years ago, Frank Egler, one of the first great, farsighted holistic ecologists, has called ecology "the science for survival". This is certainly true also for landscape ecology. Its subject is the study of landscapes as the tangible structural and functional matrix for all living organisms (including humans), their populations and ecosystems. Therefore its major challenge should be helping to overcome the present, severe ecological crisis by ensuring the future of healthy, attractive and productive landscapes, in which both natural and human life can flourish. For the provision of practical solutions to this crisis landscape ecology has to be both a problem-studying science and "applied" problem-solving oriented science. This anthology is providing convincing proof that this cannot be accomplished without developing its own, sound conceptional and theoretical basis. Therefore instead of calling landscape ecology an "applied science", contemporary landscape ecology, could be called a "crisis-solving oriented science".

In this volume, the major issues of contemporary German landscape ecology are presented in seven chapters, each one subdivided into several subchapters by different authors. As could be expected from the above-mentioned different backgrounds of these authors, they differ sometimes in their terminologies and approaches. But they are all united in their holistic view of landscapes and landscape ecology realizing it as problem-studying and solving oriented transdisciplinary science. These chapters are accompanied by an admirable collection of relevant photos of landscapes from all over the world, all taken personally by Olaf Bastian and they contain a great number of instructive models and figures. The references cited are not restricted only to the specific German context, but deal with landscape ecology and all other relevant themes on an international and interdisciplinary scale which is, unfortunately not achieved by most of the other recent English landscape ecological publications which appeared recently.

Before dealing briefly with its contents, I would like to make some critical remarks on the term "geo-ecology" mentioned often in this volume as a synonym for landscape ecology. Thanks to the strong German geo-botanical tradition and the influence of geo-sciences, much attention is, rightly, paid in almost all chapters to the geomorphological and pedogenic landscape attributes, which are often neglected by so many "modern" ecologists. However this does not justify the reduction of the science of landscape ecology into "geo-ecology". As shown very lucidly in this volume, landscape ecology has to deal in a holistic way with landscapes as complex systems in which natural geospheric and biospheric processes are closely interwoven with noospheric human mind events, to be studied jointly by geo-bio-and human ecological tools. The kind of landscape ecology presented here is therefore much more than "geo-ecology" and should not be coined as such.

The first chapter provides a thorough description of German landscape ecology "from the roots to the present". It introduces among others the **"Neef School of Landscape Ecology",** called after the prominent geographer who established a very creative landscape ecology research group in the Saxonian Academy of Science in Leipzig and Dresden. Developing independently in East Germany, it had also great influence on the development of landscape ecology in other East European countries. However, because of the Iron Curtain it was even less known than its western German counterpart in the English speaking world.

In both countries the **ecotope** became the basic landscape study unit, functionally corresponding with the ecosystem. Therefore it seems superfluous to create an additional term of "landscape ecosystem". In their efforts for comprehensive research methods of ecotopes along horizontal – geographic - and vertical- ecological – scales, German landscape ecologists developed several other, useful concepts, such as **differential and complex site analysis, landscape ecological catena, landscape balance capacity** and others.

To the important subject of **transdisciplinarity** as special subchapter has been devoted by B. and G. Tress. Following the great systems philosopher and planner, Erich Jantsch, they outlined the differences between multi-inter- and transdisciplinarity in landscape ecology. They maintain that holistic landscape research requires a transdisciplinary approach, bridging between the traditional scientific disciplines and between science and society. This is part of the new meta-disciplinary landscape ecology, as opposed to the conventional disciplinary landscape ecology, based on the more loosely connected geographical and ecological multidisciplinary approaches. They present the **Total Human Ecosystem** as the complex sum of all landscapes, interacting with human beings and as the conceptual supra-system for the geosphere, biosphere and noosphere. Here it is worthwhile to add that we regard solar energy -powered **biosphere landscapes** and human- made fossil fuel powered **technosphere landscapes** as the concrete three-dimensional systems of our Total Human Ecosystem (Naveh and Lieberman 1994, Naveh 2002).

In the concluding subchapter M. Potschin provides some interesting observations on the contrasting views of landscape ecology by German, USA, Canadian and UK scientists. In her opinion, this diversity by itself is not a problem, as long as we consider it in a broad inter-transdisciplinary context and as its unique feature of "a movement that seeks to transcend traditional subject boundaries and understand environmental patterns and processes in a broader context."

The further chapters dive more deeply into the conceptual and methodological framework of German landscape ecology and some of the above-mentioned terms are further developed. In chapter 2, a new term **"econ"** is suggested by J. Löffler as the smallest definable spatial unit of the landscape complex, as a representative part of the mappable ecotope. U. Steinhardt presents several other new "landscape ecological paradigms" namely **correlation-hierarchy-polarity,** which should be essential parts of transdisciplinary landscape ecology,

The unique methodology of the three steps of **landscape analysis, synthesis and diagnosis,** as one of the major cornerstones of German landscape ecology, are discussed in the following chapter in a very thorough manner and with many relevant examples from the extensive studies carried out by the authors of this chapter. Here the importance of the ecotope concept becomes very obvious, because the whole methodological procedure of landscape analysis within the topological dimension is based upon it. These are complemented by the authors of this volume with a critical review of the contribution of **indicators** to landscape analysis and an interesting comparison with that carried out (by only a few!) landscape ecologists in the USA.

The next chapter is devoted to **landscape changes and monitoring**, including a future-oriented contribution on **landscape prognosis** by C. Beierkuhnlein.

In chapter 5 **landscape assessment** is discussed very lucidly and in much detail in relation to **ecological carrying capacity and stability, natural potentials and functions**. Here, like in the previous chapter it s very evident that German landscape ecologists pay much attention to basic ecotope site factors as affected by human land use and are not concerned very much with landscape heterogeneity and its mathematical formalization, which has little practical value for resolving the pressing ecological problems of their landscapes. On the other hand, important mathematical models are suggested for **multi-criteria optimization** to reconcile between different goals, functions and their evaluation.

The transdisciplinary nature of landscape assessment is very apparent in the important contribution by E. Panse on **landscape perception and aesthetics**. In this subchapter, like in the previous ones, the theoretical and epistemological discourse is closely coupled with practical problems, and in this case with landscape planning and design. Here, as far as known to me, for the first time in a landscape ecological publication, the problem of the siting of "wind parks" is elaborated. Their importance is growing rapidly together with the increasing demand for cheaper alternatives of "green energy" supply. Landscape ecologists and planners will have to deal more and more with the implications of the present transformation from the industrial to the information society and the dilemma arising between the conservation of open land for recreation and nature parks on one hand, and the need of large areas for such regenerative and non-polluting solar and wind energy installations.

In chapter 7 problems of **landscape mapping, GIS and remote sensing** are critically reviewed. Although these methods, like those in the previous chapter are applied in general by all landscape ecologists, their comprehensive treatment in these chapters, enriched by many references from German studies, will be a most valuable contribution to the development and improvement of our most important holistic tools for landscape study, planning and management.

The last chapter on **applications of landscape ecology** is the longest one; embracing the broad scope of problem-solving oriented landscape research in which German and Swiss landscape ecologists are involved presently. It is very characteristic for the transdisciplinary conception of the editors and authors of this volume that instead of plunging directly into the practical landscape aspects of planning, farmin g, tourism, nature and culture conservation, sustainable development of urban regions, urban ecology and restoration ecology, this chapter is opened by more fundamental and principal aspects. The first subchapter by K. Ott on **landscape ethics and sustainability** is a timely reminder that all these activities of landscape study and management– as well as those discussed in the previous chapters- should be guided by a philosophical landscape ethics of **what should be done** and **what should be its overarching and final goal.** For this goal we have now, fortunately a generally accepted term, namely **sustainability** in its broadest, ecological and cultural and social sense.

In a similar vain, in the following subchapter on, O. Bastian defines the **essential ecological and aesthetic objectives and target systems in space and time scales** which should be visualized as guiding pictures ("Leitbilder" in German).

In the very last subchapter of the book A. Bosshard rises again an important fundamental principle for landscape ecology, namely **participation of different actors in the landscape.** He maintains that participation in its effective, fundamental sense, based on the epistemological principle of complementarity, includes the conviction that participative solutions will be better than planning, resulting from the contributions of a few planners or biologists.

Here it should be added that in order to reach such participation, landscape ecologists should not be consented to publish their results as "semantic" information in scientific books, journals and reports, but should transfer them in to more useful "pragmatic" information –senso Weizsaeker (1974), which becomes meaningful by its effects on the receiver and its expressed in its action.

In concluding, it seems to me the editors and the many other contributors have succeeded to present in this anthology a comprehensive state of the art of German landscape ecology, its conception, methods and heir application. This will, undoubtedly, open new vistas for all those who are ready to accept new ideas to enrich and improve their own work. In my opinion, there are three major consequences which can be drawn from this volume:

1. Landscape ecology is a synthetic science in which theoretical and practical aspects are closely interwoven by synergistic, mutually amplifying interactions.

2. Landscape ecology is not a "virtual science" which can be carried out merely by sitting behind the computer in an air conditioned office. It is first of all a **field science,** by which the basic bio-geo-and human ecological data have to be collected. But their evaluation and synthesis has to be carried out

with the help of the most advanced and sophisticated tools provide presently by the information technology.

3. Landscape ecology should not be considered merely as a scientific and technical field, rooted in the natural sciences, as implied by "geo-ecology". As a transdisciplinary science. It has to include also the socio-cultural realms, as integral parts of every landscape, rooted in the social sciences and humanities.

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Chapter 1

Landscape and landscape ecology

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1.1 The landscape concept (What is a landscape?)

The question: "What is a landscape?" is problematic. The difficulty associated with the question has its roots in the "normality" of the term "landscape" , because it is part of the colloquial speech. This situation is comparable with those we face when dealing with the words "environment" or "recreation" - everybody "knows" what the words mean but they have their own special definitions and opinions about the concepts. We find the same difficulty in the scientific community when they deal with landscape related research topics. If we consider "landscape ecology" which consists of several different disciplines, we find several different definitions for the term "landscape" in the literature. The definition often depends on the "working scale" of the sub-discipline or the particular focus. We therefore consider here the historical development of the term "landscape" in the context of European Landscape Ecology.

From the beginning, the understanding of the term "landscape" is related to the perception, observation and view of the environment or living space of man. Asking a seven-year old boy-child about his definition, he listed: "...a lot of pasture, a couple of trees, forest, plants, animals, farmland, NO (!) towns, a river and a lake", which shows also this mentioned perceptional-aesthetic view. Naveh and Lieberman (1994) noted the first "visual-aesthetic connotation" of landscape in the book of Psalms (48.2) as, perhaps, the earliest reference to "landscape" in world literature.

In spite of the changes in meaning that the term "landscape" has undergone this "original visual-perceptual and aesthetic" theme has been adopted both in literature and art, and is still used by many people involved in land-

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scape planning and design, and by gardeners" (Naveh and Lieberman 1994). In contrast to North American approaches, in European Landscape Ecology, "landscape" is mostly treated as a system, as a holistic concept that takes in the interrelations between biotic and abiotic components, as well as the human impact upon them. As a result, the analysis of landscape requires an integrated approach (Figure 1.1-1).

Figure 1.1-1: Landscapes comprehend both the abiotic and the biotic components, as well as land use: View of Cres (Croatia) (Photo: O. Bastian 2001)

A. v. Humboldt, the great German geo-scientist, defined "landscape" in the early 19th ^{c}entury as "the total impression of a[n] earth region". Most of the landscape ecologists within geography believe that this definition is related to the landscape as a whole. With the development and specialization of the branches of geo-sciences during more recent times, this view has been seen as more and more "narrow".

Russian geographers, for example, have approached given a much broader interpretation of the concept of landscape, including both biotic and abiotic components. Troll (1970) himself defined landscape as "the total spatial and visual entity of human living space, integrating the geosphere with the biosphere and its noospheric man-made artifacts" (Naveh and Lieberman 1994). In 1939, Troll coined the term "landscape ecology", using the idea to stimulate co-operation between geographers and biologists using aerial photographic interpretation of landscapes (Troll 1939). In doing so, Troll hoped to fulfill his vision of a unified field of earth and life research, a new branch of "ecoscience". In Germany, the geographers who took up "Troll's" Landscape Ecology developed the idea of an integrated landscape view further, both theoretically and philosophically. Discussions about the definition of landscape were closely related to the discussion about the definition of geography itself (Turba-Jurczyk 1990). It should be noted in this context that in Germany "ecological" landscape research was carried out before Troll's time (1939). Studies such as those of Penck (1924, 1941), for instance, had already posed questions at the beginning of the 20th century about the carrying capacity of the earth, and Passarge (1912) talked about **landscape physiology** (Finke 1994).

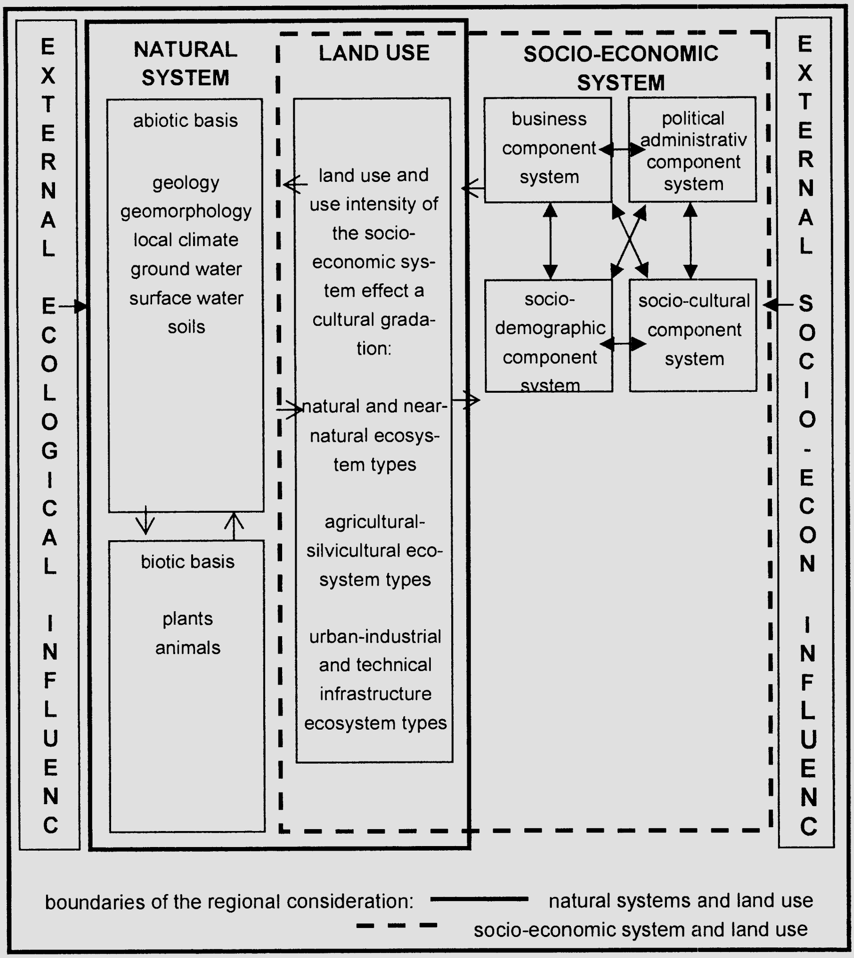

Figure 1.1-2: Schematic presentation of a regional socio-economic ecological system (according to Messerli and Messerli 1979)

Figure 1.1-3: Landscapes are parts of the earth surface with an uniform structure and functional pattern: Cereal fields in the Moritzburg Small Hill Landscape (Saxony, Germany) after the harvest (Photo: O. Bastian 2001)

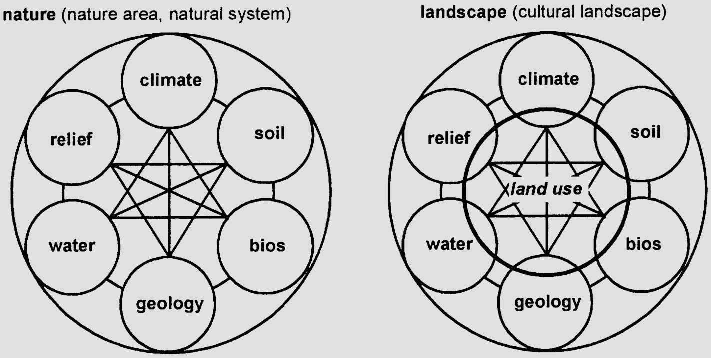

Figure 1.1-4: The landscape concept: According to Neef 1967 and Haase et al. 1991 landscape can be defined as a part of the earth's surface signed by the natural configuration and superimposed by human intervention

The development of Landscape Ecology within geography depends also directly on the discussion about the definition of the term landscape (Bartels 1968, Bobek and Schmithüsen 1949, Neef 1967, Schmithüsen 1963, Turba-Jurczyk 1990). Neef (1967) defined landscape as "... an integrative structure and identic process texture characterized special part of the earth surface", which can be counted as still valid today (Bastian and Schreiber 1999, Figure 1.1-3). Hence landscapes comprehend both the **abiotic and the biotic component**, as well as **land use** (Figure 1.1-2 and 1.1-4). Land use acts as an interface between natural- and socio-economic systems. Landscapes are subject to permanent changes and development due to the natural processes taking place in them and their human use. This use of landscapes results from the **working and living activities of people** (Figure 1.1-5).

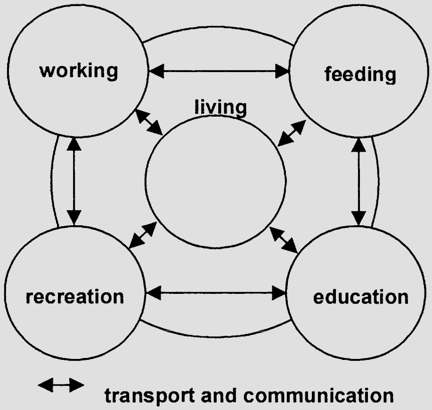

Figure 1.1-5: Basic human needs: fundamental human activities that are immanent in all social ranks and that can be measured temporally and spatially. The number of basic human needs depends on the cultural group as well as the epoch. Our basic human needs are living, working, feeding, recreation and education within communities. Transport and communication are not considered as basic human needs, although they are essential activities for their realization

The overlay of social demands on nature results from the aspirations of people and complex socio-economic interactions. As a result, the production-oriented use of landscapes leads to or contributes to very different environmental stresses. These include the greenhouse effect and depletion of the ozone layer, eutrophication, acidification, toxic contamination, the loss of biodiversity, pollution and consumption of soil, water, forest and marine resources, waste dumping, the consumption and destruction of land, the decrease in environmental quality in urban areas stemming from air, water and soil pollution, noise, and the sealing of land. The change of both land use and cultivation practices, such as ploughing, fertilization, draining, sealing of soil, is one of the most visible features of landscape change and its far-reaching ecological consequences (see Chapter 4.1). Due to natural changes and in view of the history of human impact, on the environment, landscape changes can occur over time scales ranging from thousands of years (e.g. climatic change since the last ice age), centuries (e.g. the cultivation of arable land, settlement, etc.), decades (change of agricultural cultivation practices, sub-urbanization, open cast mining, changes of the weather sequences and water balance, etc.) and years (e.g. crop rotations) to single years (e.g. seasons, phenology and land cover), or even individual (short-term) events (volcanic eruption, earthquakes, flooding). Thus, landscapes have a history (genesis), a current condition or state, and a developmental pathway, as well as a potential natural condition or state (as an abstraction of the current or real landscape). They include renewable and unrenewable **natural resources and potential** use or value. Against this complex background, people aspire to particular conditions of the landscape corresponding to their system of values and demands. But landscapes, like other systems, can exhibit fluctuations around an equilibrium state or in the face of interference a certain resilience to change. Anthropogenic objects and influences activities also have a more or less capacious potential of persistence against change. Thus, cultural landscapes develop as the result of an interplay between the forces of persistence and change (see Chapter 5.1).

A central point of discussions that have ranged over the last decade about the term landscape was the question of whether landscapes are unique or whether types can be identified (Paffen 1953, Schmithüsen 1964). Landscape physiologists developed a theory that the landscape is a synthesis of a multitude of single elements. Later on, this theory became important in landscape ecology.

Another important question explored in discussions about the term landscape was that about spatial dimensions. Thus, Troll (1950) refused to accept the smallest units of nature areas (**physiotopes**, **ecotopes**) as landscapes. In his definition, the term landscape is suitable only up to a typical spatial composition or distribution (**mosaic** of physiotopes or ecotopes). On the other hand, Carol (1957) and Neef (1967) held the view that the size of an area and the direct related exclusion of "wholes" cannot be used as a definition criterion for landscapes. In the disciplines related to landscape ecology, discussion about the central term of geography had also led to confusion rather than to clarification (Finke 1994, Trepl 1987). In these disciplines, especially in the planning branches, a more "unworried" handling with the term landscape can be observed.

Nevertheless, at the beginning of each study dealing with landscape and environment related problems, a definition should be given of what is meant by the term landscape and in which sense it is being used. The definition can depend, for example, on the dominant view, namely whether it is geographical, cultural, functional, and aesthetic or whether other aspects are of interest (Wenkel 1999). A definition given by Haase et al. (1991) in the context of landscape modeling which emphasizes the steps involved when translating from a real landscape to a corresponding landscape model illustrates the process more transparently. According to their definition, landscape is a part of a region that is pre-formed by the natural conditions and more or less shaped and influenced by cultivation and land use. Landscape forms a spatio-temporal structure with interactions between nature and society in it.

From a structural view, a landscape is a mosaic of smallest homogenous spatial units (the topes), from a more functional view it can be described as an ensemble of ecosystems. More simply, Turner and Gardner (1991) considered a landscape to be a spatially heterogeneous area. In a similar vein to the ideas of Haase et al. (1991), Forman and Godron (1986) suggest three landscape characteristics that are useful to consider when thinking about landscape: structure, function, and change. "**Structure** refers to the spatial relationships between distinctive ecosystems, that is, the distribution of energy, materials, and species in relation to the sizes, shapes, numbers, kinds, and configurations of components. **Function** refers to the interactions between the spatial elements, that is, the flow of energy, materials, and organisms among the component ecosystems (but pay attention to the different meaning of landscape function in Chapter 5.2!). **Change** refers to alteration in the structure and function of the ecological mosaic through time" (Turner and Gardner 1991a).

In spite of the discussion between the different disciplines and groups of landscape ecology about the definition of the term landscape, new discussions and questions about the concept arise as the result of the increasing cooperation between of landscape ecologists with economists and socio-economists, in relation to debates about sustainable development. Dabbert et al. (1999) explore this problem in their book about a integrated ecological-economic method for landscape modeling. They point out that in the landscape related sciences, terms like "region" and "regionalization" are used and develop over long periods. Dabbert et al. (1999) cite Grisebach (1872) and Schimper (1898) as examples of writers talking about "biogeographic regions" as early as the end of the 19th Century. These terms have held up and can be found also in he more recent literature (Müller 1980). From the view of plant ecology, "regions" are the subdivisions of "floristic realms", or "biorealms", in which the differences of macroclimatic conditions become obvious. Considering discussions about landscape, a broader ecological definition of "region" would refer to landscape areas, consisting of similar geological-morphological complexes defined by traditionally similar land use mosaics. These land use mosaics again are reflecting these environmental complexes. In modern agricultural cultivation systems and in the landscape structure, these traditional structures of primary production are often visible today – in spite of variegated changes.

Dabbert et al. (1999) used the term "landscape" in place of "region", making clear their interest in content of spatial ecological and agriculture related economic effects. From a spatial point of view, they identify landscapes as units corresponding approximately to the German **classification of nature areas** ("Naturräumliche Gliederung", Meynen and Schmithüsen 1953-1962, see Chapters 1.2.3 and 2.4.5). With this, they prefer a more pragmatic definition for their integrated approach, but nevertheless, a well grounded one. It seems to be difficult to find a correct translation of the German term "Naturraum": sometimes "natural area" is used, other authors choose "natural sphere" or "natural unit of landscape" and some colleagues prefer "physical region". With respect to content all terms refer to the entirety of natural elements presented in the left part of Figure 1.1.-4. For this book we tried to harmonize this confusion and use the term "nature area".

Considering the various answers that have been given to the question: "What is a landscape?", some general statements can made, for all disciplines of landscape ecology (the following statements are in accordance with a compilation of Forman and Godron 1986, Hansen and Di Castri 1992, Klijn 1995, Turner 1987, Urban et al. 1987, Zonneveld and Forman 1990):

- Landscapes are nearly always the result of both natural and man-induced processes during, nearly always, various time-scales. Landscapes can effectively be described as palimpsests, **patterns superimposed on each other**, showing features of different eras. These legacies affect present-day and future processes.
- **Landscapes are changing**, but changes occur at different rates, either gradually or suddenly, even catastrophically. Landscapes that are stable for a long period are almost fiction.
- Nevertheless there are **stabilizing forces within landscapes**: disturbances are followed by a return to a former status or by a new equilibrium, both in a physico-chemical and in a biological sense.
- Although landscape dynamics show many unexpected or unexplainable phenomena, there is still a **large portion of predictable change** such as primary or secondary succession or degradation stages.
- Landscape are mainly **open systems**: open to vertical influences (e.g. radiation, atmosphere), open to influences from their surroundings and internally open (exchange between patches within one landscape). Landscapes can be understood by insight into the **flows of matter, energy and organisms**.
- **Landscapes are heterogeneous**, both in a vertical and horizontal direction. Vertically one can distinguish layers (atmosphere, canopy, soil, groundwater, rock, etc.). Horizontally, landscapes consist of patches (or ecotopes) with repeat themselves in a certain pattern. Between "homogenous" patches are boundaries that can be sharp or gradual. Boundaries are sometimes open to the exchange of matter, energy or organisms; they sometimes act as barriers or membranes.
- Landscapes are perceived as parts of the earth's surface with **a certain size but with uncertain lower and upper limits**. Questions are open concerning the spatio-temporal definition of landscapes, so that it is not

possible to derive any standard sizes or scales. The definition depends on the priority of view.

In the authors' opinion, these statements contain all relevant characteristics (and also open questions) of (and about) landscapes and their role in landscape ecology.

Discussions about the **landscape concept** are closely related to those surrounding the **ecosystem concept**. Northern American (landscape) ecology has deep roots in biology. So their perception of landscape and landscape ecology differs more or less from the European (see Chapter 1.4, for a discussion of the "ecosystem" term see Chapter 1.2). Following the definition of Chapin (2001) ecosystem ecology links the study of organisms and the physical environment with the functioning of the Earth System. An **ecosystem** is defined as consisting of all the organisms and the abiotic pools with which they interact, and **ecosystem processes** are defined as all the transfers of energy and materials from one pool to another. Hence **ecosystem ecology** addresses the interactions between organisms and their environment as an integrated system. At first sight this approach seems to follow the European approach to landscape and landscape ecology. But in the strict sense the US-approach marks-off a boundary between organisms on the one hand and their environment on the other, especially between organisms and their abiotic environment. In most cases the focus of scientific work in the field of ecosystem ecology is to

- trophic interactions: the feeding relationships among organisms - food-webs and foodchains (e.g. Pimm 1982, 1984, Power 1992),
- species distribution, populations (Watts 1999),
- habitat fragmentation (Dunning 1999),
- succession: long-term directional changes in community composition (Vitousek and Reiners 1975),
- resilience of ecosystem properties following disturbance (Turner et al. 2001), and
- biodiversity (D'Antonio and Vitousek 1992).

Often (abiotic) environmental conditions are only considered insofar as they are essential for the explanation of the organisms' occurrence or behavior: atmosphere, oceans and climate as well as geology and soils are considered as a background of the ecosystem but not as an inherent part of the system. But also human can't be excluded – they are an inseparable integral part of the environmental system (Haber 1996, 2001). Chapin's term **ecosystem** bears a comparison with our term **physical region** but has nothing to do with **landscape** in the sense discussed above. A holistic view to the whole system is missed. This points up, that the use of the landscape term is often restricted to a specific scale but not to a system that integrates abiotic and biotic environment as well as land use representing the interface between the natural system and the socio-economic system.

1.2 Landscape ecology: From the roots to the present

1.2.1 Basic terminology

Landscape ecology (the ecological consideration of geographical areas) has diverse roots stemming from biology, geography and even forestry. The term **ecology,** meaning the science of the relationships between an organism and its surroundings, was coined by the German zoologist Haeckel (1866). From a modern point of view, this is a definition of autecology, which describes the relationships of an individual with its environment. The first ecological publication based on field studies was written by the zoologist Möbius (1877) and dealt with the oyster and the oyster industry. It was him who introduced the term **biocoenosis** or **community of species**, providing a solid basis for the vague ideas already extant about the co-existence of organisms. He understood biocoenosis in means of a group of organisms inhabiting a distinct, delimited area according to the number and the type because they correspond to the average external living conditions of the area, engender each other, and persist in the long term by means of reproduction. External living conditions are understood as for instance a suitable soil, sufficient nutrition, and in the case of the oyster-beds a suitable level of salt in the sea water and a temperature favorable for both development and survival. He also noted that if any of the factors co-determining the biocenosis changed, this would affect other factors. This was probably the first synecological study which matches our current understanding of the term.

The term **ecology** was mainly introduced into international practice by the Danish botanist Waming (1909) thanks to his "Ecology of Plants".

Right from the start, ecological research combined geoscientific and biological issues, such as when Clements (1905, 1916) and Cowles (1899) studied the laws of development of biocoenoses against the background of the continuous development of the soil, and Cowles (1899) observed the plant succession taking place on the sand dunes of Lake Michigan. This was the beginning of succession research and made Chicago a center of American plant ecology. It was in 1899, too, that Davis published "The Geographical Cycle", which later came in for heavy criticism owing to its purely deductive reasoning. Nevertheless, the influence of geography even made Cowles (1911) drop his concept of succession in favor of the cycle.

The broadening of ecology's holistic approach to whole sections of the landscape by the term **landscape ecology** was nothing more than the consistent development of ecology's original biological background. Troll, who had taken a degree in biology and specialized in plant geography, introduced the term in a publication on the application of aerial photography using the example of tropical areas with different vegetation densities (Troll 1939). At that time, the new technique of aerial photography enabled for the first time a bird's eye view of the landscape, allowing various phenomena of an area to be holistically observed and interpreted. Vegetation is an important indicator of differences between biotopes. Troll was quick to spot the possibilities afforded by aerial photography for geographical research (see Chapter 6.3), especially when combined with ecological soil research. In a now famous paper on landscape ecology at the "Plant sociology and Landscape Ecology" symposium in 1963 in Stolzenau/Weser, Troll delivered a definition of his concept of landscape ecology. This definition has since been repeatedly quoted since it clearly summed up his idea of research into the relationships between organisms and their surroundings in a specific area. It describes landscape ecology as the study of the entire complex cause-effect network between communities of species (biocoenoses) and their environmental conditions in a certain landscape. The cause-effect structure in landscape ecology is spatially expressed in a certain typical landscape pattern ("Naturräumliche Gliederung"), which translates as the definition of nature areas on the basis of physical criteria. It can be studied at various scales, each with its own specific methods. Smaller nature areas can be aggregated in terms of their cause-effect structure within landscape ecology effect structure and their geochorological relations into larger units. This results in a hierarchical system from the smallest homogeneous nature area, the **ecotope** (which functionally corresponds to an ecosystem) through medium-sized areas to ecozones. This definition of areas is an important basis for modern landscape ecology.

Owing to its easier translatability into English, Troll himself (1968) proposed replacing his term **landscape ecology** by **geoecology**. Consequently, both "Landschaftsökologie" and "Geoökologie" are commonly found in the German-language literature. By contrast, Leser (1997) regards geoecology to be only the physio-geographic branch of landscape ecology.

The complex of interactions between organisms and their environmental conditions is nowadays summed up under the term **ecosystem**. It is in this sense that the ecosystem (a functional unit between organisms and their environment) is generally regarded as the object of research of ecologists. The German zoologist Woltereck (1928) was the first who utilized the term "eclogical system". In contrast English literature refers to Tansley (1935) who introduced the term "ecosystem" into technical literature. According to the popular definition by Ellenberg (1973), an ecosystem is a cause–effect structure of living things and their inorganic environment, which although open is capable of a certain degree of self-regulation.

All definitions of ecosystem involve the links between inorganic components (studied by the geosciences) and biotic components (the subject of biology). However, dissent recently emerged concerning the development of the ecosystem by Leser (1997) in the **landscape ecosystem**. Some ecologists, especially those with a background in biology, believe like Schreiber and Opp (1999) that this expansion of the term is superfluous since ecosystem already includes the abiotic components of the landscape interacting with living things. However, it can hardly be denied that the spatial objects investigated by landscape ecologists are substantially greater than the functional units between living things and their environment dubbed by biologists an ecosystem. For example, landscape ecology also includes the transmission of material and energy within a geosystem, i.e. the emergence of certain environmental conditions before they take ecophysiological effect.

1.2.2 The beginnings of ecological landscape research in Germany

The development of ecological landscape research can for simplicity's sake be divided into the following phases of development:

- holistically descriptive – partly analytical,
- qualitatively analytical – quantitatively analytical,
- structurally orientated – process-orientated, and
- landscape-form orientated – system-orientated.

This classification chiefly refers to ecotopes as the smallest spatial objects of investigation of landscape ecology orientated towards nature areas. It indicates the increasing progress of the methods of geoecological exploration and hence chronological development. The development of methods of investigation and the resulting improved accuracy of findings has been accompanied by an increase in practical applications of landscape ecology.

The development of ecological landscape research in Germany was above all introduced by the methodologically exemplary publications by Paffen (1948, 1950, 1953) and Schmithüsen (1948, 1949). In a model study using the example of the central and lower Rhineland, Paffen (1953), a student and later co-worker of Troll, developed the theoretical and methodological fundamentals for ecological landscape division. He started by defining ecotopes as the basic unit of ecological land classification (which he referred to as **landscape cells** – a term which rightly did not catch on) and showed how they can be aggregated to form larger units of nature area. Each nature area higher up the spatial scale comprises a certain number of ecotopes, usually with typical patterns of recurrence and spatial networking. This means that each nature area higher up to the scale is ecologically heterogeneous. Paffen (1953) recognized the defining role of relief in the formation of ecotopes, describing them as **topographic-ecological complexes**. All in all, he identified seven hierarchical stages of nature areas. His standard maps of the ecotope structure of landscapes in the lower Rhineland, Eifel (a plateau region in Germany between the River Moselle and the Belgian frontier) and the central Rhineland, as well as his 1:400,000 map dividing the central and lower Rhineland into nature areas, provided examples for subsequent investigations in the field of ecological landscape analysis and the definition of nature areas.

As early as 1942, Schmithüsen grasped the importance of vegetation studies and ecological site classification for geography. Like Troll and Paffen, he specialized in vegetation geography, writing for example an internationally acclaimed textbook on vegetation geography (Schmithüsen 3rd edition 1968). He started by producing standard maps of the ecological spatial patterns of various landscapes, and showed that each landscape consists of a spatial structure of different ecotope types linked up in their own specific manner. The way in which they are interlinked is not just a formal characteristic, but frequently also an expression of certain lateral processes involving the exchange of material and energy (e.g. slope catenas), which were initially described by **neighborhood effects** (Paffen 1953).

Figure 1.2-1: The forest site mapping is one of the roots of modern landscape ecology in Germany. Spruce forest in the Erzgebirge Mountains (Saxony, Germany) (Photo: O. Bastian 1978)

The concept of large-scale definition was in particular adopted for the **mapping of forest sites**. It was carried out systematically in Germany, especially in the state forests as of 1936, at the instigation of Krauss, and formed the basis for forest planning (Figure 1.2-1). The forest sites largely correspond to ecotopes, as underlined by Schmithüsen (1953).

1.2.3 The definition of nature areas in Germany

One major project preceding modern landscape ecology was the definition of nature areas in Germany pursued by the "Institut für Landeskunde" (Institute of Regional Studies) under the direction of Meynen. The theoretical principles for the project were largely developed by Schmithüsen (1949, 1953). Working under the auspices of the Federal administration in Germany, the institute was a scientific advisory body to the government. It was expected to survey the entire territory of the state. Starting in around 1949, nature areas in Germany were jointly defined at two different scales by a large number of German geographers.

1. "**Handbuch der naturräumlichen Gliederung Deutschlands**" (Manual of the definition of nature areas in Germany) featuring a 1:1 million map, published by Meynen and Schmithüsen et al. (1953–62, see Chapter 6.1.2). It shows the entire territory of Germany within its current borders as drawn up by geographers at a time when Germany was divided.
2. "**Geographische Landesaufnahme 1:200 000, naturräumliche Gliederung Deutschlands**" (Geographical survey 1:200,000, definition of nature areas in Germany). Each map sheet comes with an explanatory booklet containing a detailed physicogeographical description of the nature areas delineated on the map. The division into nature areas on a scale of 1:200,000 only covers the territory of western Germany (i.e. the area known as the Federal Republic of Germany until German unification on 3 October 1990).

The 1:200,000 maps improved the detail of the definition of nature areas in the 1:1 million maps.

Although Schmithüsen's theoretical approach (1953) for the natural division of Germany was certainly landscape ecological in accordance with the level of research at that time, its implementation lacked uniformity owing to the large numbers of scholars involved in the descriptive texts. Coming from a variety of different backgrounds, some authors performed subdivision on the basis of morphographical or climatic factors, while others focused more on aspects of vegetation ecology. The great achievement of this classification into nature areas is above all the systematic survey and description of the entire country.

The division of Germany into nature areas at a scale of 1:1 million and 1:200,000 enabled statistical and practical questions to be tackled. For example, it provided a basis for regional agricultural statistics. The 1:1 million map (or excerpts thereof) is contained in various atlases such as "Die Bundesrepublik Deutschland in Karten" (The Federal Republic of Germany in maps) and the regional climatic atlases published by the German meteorological service. Richter (1965) used the 1:1 million classification to estimate the risk of soil erosion and then developed related maps.

The maps showing natural areas are merely boundary maps and do not indicate what the areas contain. Nevertheless, the boundary lines are the most questionable aspect of natural division. What really matters is the make-up of the areas, i.e. the landscape ecological cause-effect structure and the geofactors on which it is based. The decision to merely show the boundary lines (doubtless a problem of such large-scale projects) is attributable to the difficult post-war situation at the institute. The subsequent development of a nature area type map for West Germany was designed to make up for this shortcoming. Renners (1991) revised the 1.1 million map of the natural division of Germany and took it as a basis to characterize the nature areas in terms of the factors relief, soil (including substrate and water balance), hygrothermal climatic regime, and (if possible) potential natural vegetation. To the contents of the natural areas of different scales see Klink (in Renners 1991).

In the mid-1960s, students of Neef in Leipzig developed large- and medium-scale examples of nature area characterization maps (Haase 1965, Hubrich 1965). These maps represented preliminary work for the 1:750,000 nature area characterization maps in the **Atlas DDR** edited by Barsch and Richter (1975). The characterization of nature areas in this map is mainly based on the complex relationships between the soil, substrate and water balance, taking into account relief. These nature area characterization maps enabled the creation of a new thematic map type synoptically showing the complex relations between a landscape's physical factors.

1.2.4 The Neef school of landscape ecology

One result of the division of Germany, which intensified in the early 1960s, was that contacts between scholars on either side of the inner-German frontier were increasingly forbidden. Nevertheless, although teams of researchers working in landscape ecology at various universities had almost no contact with their colleagues on the "other side", they still arrived at largely similar findings (Figure 1.2-2). Mention should be made of the researchers headed by Neef, first in Leipzig and later in Dresden, who made a vital contribution to the creation and development of methods of nature area exploration and landscape ecology. This group is even mentioned in the literature as the "Neef school" (Haase 1996).

Of Neef's students, mention is only made here of G. Haase, K. Herz, H. Hubrich, R. Schmidt, H. Richter and K. Billwitz, who largely contributed to the development of landscape ecological theory and land-surveying methodology. They developed techniques of both analysis and presentation. One important factor was the soil as an integrative component of the landscape ecosystem (Haase 1961, 1964, 1967, Hubrich 1964 a,b, Schmidt 1984). During studies of the soil moisture in various soils in Saxony, Neef et al. (1961) identified the soil moisture regime, the soil type and the vegetation as **main landscape ecological features** with integrative characteristics. Such components explaining much about the ins and outs of the ecosystem formed the basis for complex site analysis (see Chapter 3.4), which quickly became established as an important method of landscape ecology.

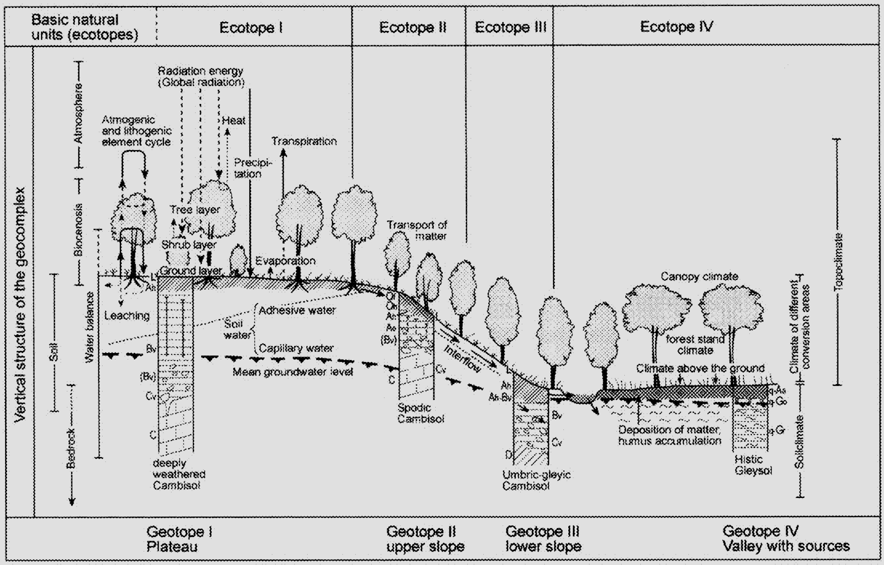

Figure 1.2-2: Structure and interacting systems of different associated ecotopes(Haase 1967, Klink 1964)

Ever since the fundamental methodological publication by Haase (1967), a distinction has been drawn in landscape ecology between differential analysis and complex site analysis. **Differential analysis** deals with partial complexes relevant to landscape ecology such as relief, climate, soil, vegetation and their components. Its thorough analysis forms the basis for an ecological **complex site analysis**, which is designed to capture and model the mainly vertically aligned functional relationships between the ecotope's components and partial complexes. Clear principles were also worked out regarding the way in which ecotopes (the smallest spatial units relevant to landscape ecology, see Chapter 2.2.2) are linked up (Haase 1973, 1976), and related standard maps were developed at medium scale (1:100,000 and 1:200,000). Synoptically showing the physicogeographical conditions, these maps acquired enormous importance over the years for regional planning, landscape planning, nature conservation and environmental protection. Above all, now that the **usage and development potential** of nature areas have been assessed (Mannsfeld 1978, 1983, Marks et al. 1992), the maps are consulted in connection with **practical decision-making**. The findings of the extensive investigations into ecologically heterogeneous nature areas at the geochorological dimension are collated in the volume edited by Haase et al. (1991) "Surveying nature areas and land usage: geochorological techniques for the analysis, mapping and assessment of nature areas" (in German).

Above all Neef himself is known for his fundamental contributions to ecological landscape theory. His goal was to capture and depict possible features of the landscape as precisely as possible, and also to provide a better foundation for the practical application of geographical findings, especially from landscape ecology. He began by tackling the basic questions of geospheric and landscape arrangement, and explained the **axioms of the concept of landscape**. Of particular importance for landscape ecology, which deals with areas of various scales, is its **theory of geographical scale** ranges or, in other words, the dimensions of the arrangement of nature areas (Neef 1963, 1967). He defined what a dimension of investigation as "... scale ranges in research which have the same information content and enable the same aims and methods." Other important contributions deal with the theory of the smallest landscape ecological spatial units, the physiotope and the ecotope (Neef 1968), and the theoretical bases of (natural) area type formation.

From his experience of the highly temporal dynamics of mountain landscapes, Dollinger (1998) points out that research into the theory of geographic dimensions still needs to be carried out with respect to the permanent temporal variability of landscapes.

A theoretical and methodological certainty was achieved in analyzing nature areas on the scale of topes (patches) and chores. Their role within the natural balance enabled the results of landscape ecology research to be applied practically to human benefit (Haase 1968, Haase and Richter 1980, Schmidt 1984, Figure 1.2-3). It was also used to evaluate whether the landscape balance of specific nature areas would be disrupted by waste disposal, water extraction, and construction projects (Haase 1978, Mannsfeld 1978, see Chapter 5.2). Another important step in the usage of scientific findings from landscape ecology for effective spatial organization and the entire socio-economic reproduction process was Mannsfeld's publication (1983) "Landschaftsanalyse und Ableitung von Naturraumpotentialen" (Landscape analysis and concluding the potential of nature areas). Working on an example area north of Dresden, he evaluated site fertility (yield potential), the likelihood of surface runoff and groundwater recharge, the disposal potential for liquid by-products and the scope for construction while simultaneously preserving important **landscape functions** on the basis of the careful exploration and mapping of nanochores.

Figure 1.2-3: Western Lusatia (Saxony, Germany) is one of the classical landscape ecological study areas of E. Neef, G. Haase, K. Mannsfeld and others (Photo: O. Bastian 1999)

Primarily with the aim of using landscape ecology research in spatial planning and usage, Neef established a research group at the **Saxon Academy of Sciences** known as "Natural balance and regional characteristics". Its investigations and resulting developments have in recent years focused on two main areas:

1. Research into the structure and dynamics of landscape ecosystems: Based on a broad stock of data, landscape functions are assessed and their reactions to human usage requirements are forecast. Surveys of the landscape at different times provide information about its changes and are used for environmental monitoring.
2. The now completed production of the set of maps entitled " Nature area sand their potential in the Free State of Saxony on a scale of 1:50,000" is based on of microchores, i.e. natural units with a certain ecotope structure (see Chapter 6.1.4). The robustness of the natural balance with respect to anthropogenic usage is evaluated and concepts are developed for the permanent, environmentally sustainable usage of the landscape. The work of the Natural balance and regional characteristics group is described in the volume edited by Haase (1999) "Contributions on land-

scape analysis and landscape diagnosis" as well as the handbook edited by Bastian and Schreiber (1999) "Analysis and ecological assessment of the landscape" (in German). These two books vividly emphasize the links between landscape ecology as a scientific discipline and its practical application.

1.2.5 Research development in West Germany

In the first half of the 1960s in West Germany, students of Czajka in Göttingen worked on strengthening the theoretical foundations and refining scientific survey methods for the large-scale classification of nature areas. Their initial aim was to depict all the structural elements of the ecotope which could be surveyed physiognomically. Their qualitative and partly already quantitative analysis techniques addressed key features of the ecosystem such as soil type, humus form, soil water, pH (as a factor controlling nutrient availability), and in particular vegetation. Their investigations were carried out in various nature areas: north German lowland (Dierschke 1969), subhercynian mountains with cuestas and hogbacks (Jung 1968, Klink 1964, 1966), and an active volcanic landscape at Mount Etna on Sicily (Werner 1973).

This work indicated other factors determining the cause–effect structure of landscape ecology and the arrangement of nature areas. In the low-mountain region, for example, such factors include the rocks and the relief along with the resulting topoclimate; in the active volcanic area they include the shape of the relief and the type and age of the volcanic rock, and in the lowlands dating back to the Ice Age with minimal relief the soil types and water balance. Another major aspect of this work consisted in studying **soil forms and vegetation** as integrative components of the ecosystem ("main ecological features" according to Neef et al. 1961, see Chapter 1.2.4). Large-scale land use for landscape ecological organization above all in mountainous areas was attributed to the **catena principle** (Klink 1964, see Chapter 2.6), while Haase (1961, 1964) introduced the term **landscape ecological catena** meaning a regularly recurring series at a site. Thanks to the link with Tüxen (who alongside Braun-Blanquet was one of the founders of plant sociology), in contrast to the Neef school more attention was paid to methods of an **ecologically interpreted plant sociology** (especially Dierschke 1969). In these studies, too, chores were delineated by principles of spatial networking (structural shapes) of ecotopes, constituting a bottom-up approach or nature area arrangement (Richter 1967).

Landscape ecological research into areas on the scale of topes and chores (lower level of hierarchy) was until long into the 1970s closely geared to the structural characteristics of ecotopes and the partial complexes of which they are comprised; except for investigations of the water balance. However, the structural factors and features were not attributed any direct eco-physiological effect, instead being regarded as factors controlling ecological processes. The main **ecological process parameters** acting directly are water, heat/light, and nutrients and pollutants, as well as mechanical influences such as the wind, animals' footprints and the impact of foraging. Process-regulating effects can be easily clarified using the example of relief with structural features such as slope incline, curvature and direction, as well as with the example of soil types (Klink 1994, Hütter 1996).

The theoretical demands made of **complex site analysis** (see Chapter 3.4) necessitate not only the exact determination of the structural factors but also surveying the ecological process parameters interlinking an ecosystem's components. One way of doing this is to use quantified material and energy balances. Another important method is to model the functional relationships within the system. Much work was done on both these approaches in particular by Leser (1978, 1983, 1984), and his former student Mosimann (1978, 1984a, 1985). Leser also wrote the **first textbook on landscape ecology** (1st edition 1976, 4th edition 1997). Another well-tried text book has been written by Finke (1986, 3rd edition 1996), who took care mainly of connecting landscape ecology with planning and nature conservation.

Nevertheless, especially Mosimann's very thorough investigations show that a complete survey of a landscape's ecosystem taking into account all its structural and process parameters is hardly possible. In the author's opinion, the limited time and resources available should therefore be concentrated on certain **key parameters** relevant to understanding how the respective ecosystem functions. Further developing the analytical survey method for structural and process parameters exacerbates the dual problems of their systematic interlinking and transferring the data acquired from isolated points to the whole area. In a nutshell, the aim of landscape ecology of being able to capture spatially related relations between biocoenosis and the environment calls for ever closer co-operation between the biosciences and the geosciences.

Schultz (1995, 2000) developed a very interesting approach in the global dimension of the definition of nature areas. He deals with **ecozones** – large areas of the Earth previously described as great regional belts, geographic zones, geozones and "Zonobiome" (major ecological climate zones) (e.g. Berg 1958–59, Haggett 1991, Müller-Hohenstein 1981, Walter and Breckle 1990-94). Each of these ecozones is a geozonal ecosystem with its own climate genesis, morphodynamics, soil formation, plant and animal species, as well as its own agricultural and forestry potential. In addition to a qualitative description of individual characteristics and combinations thereof, such as climatic features, soil forms, vegetation formations and land usage types, the quantitative and integrative survey of material and energy stocks in the various compartments of the ecosystem is also of importance. Furthermore, typical matter and energy turnovers between the compartments are shown. Ecologically important stocks of matter include for example the biomass of plants and animals, the dead organic soil substance, and mineral substances in the vegetation and the soil. As far as material turnover is concerned, particular attention is paid to primary products, animal forage and secondary production, litter fall and decomposition, as well as mineral substance and water cycles. Energy aspects are taken into account for all organic substances and their turnover. This ecozonal treatment has been enabled by the findings of ecosystem research made regionally available in abundance over the past three decades.

On the basis of the state-of-the-art methodology documented in particular in the publications by Mosimann (in Leser 1997), in 1984 a team of university geographers and experienced practitioners from the spheres of spatial planning, urban development, nature conservation and environmental protection was formed in West Germany. It described itself (for instance at the German Geographers' Conference in Munich in 1987) as the **Geoecological Spatial Division and Landscape Balance Capacity Study Group**. The group's declared aims were to promote small-scale geoecological research and its practical usage. As well as exposing methodological shortcomings in small-scale ecological surveys, and capturing and characterizing ecologically effective structural landscape elements and processes of the landscape balance, its aims included developing mapping instructions for surveys in the small-scale range using methods which were technically flawless yet relatively simple to use (GÖK 1:25 000, Leser and Klink 1988). The group produced a methodological handbook on **small-scale geoecological mapping** and presentation and instructions for the appraisal of the **capacity of the landscape balance** edited by Marks et al. (1989, 2nd edition 1992). Both publications stimulated work on landscape ecology in Germany and in other German-speaking countries in a variety of ways, and contributed to its practical implementation. In particular, the instructions regarding the assessment of the capacity of the landscape balance were warmly welcomed by practitioners working in public authorities, private planning companies and consulting firms. In order to avoid a merely anthropogenic viewpoint and to take into consideration the various "services" of the landscape balance for spontaneously developing biocoenosis of plants and animals, i.e. for nature itself, the term "potential of nature area" used by for example Mannsfeld (1978) was after thorough internal discussion replaced by the capacity ("Leistungsvermögen") of the landscape budget.

A new edition of the handbook was published along with modified mapping instructions (Leser and Klink 1988) in which landscape ecological surveying standards and their operationalization were emphasized in an effort to achieve versatile, flexible usage beyond the realm of mapping. More attention was also paid to the treatment and homogenization of available data using methods of information technology (Zepp and Müller 1999). It is planned to revise the assessment instructions, with more emphasis being placed on aspects of value theory and regionally specific landscape models (Zepp 1998).

Another relevant task is the **extrapolation** of the isolated findings (especially process data) obtained via the **tesserae** in order to conclude spatial information. A whole range of techniques is available, including estimation, fuzzy logic methods, neuronal networks, computer-based model simulations, data management and modeling in geographic information systems (see Chapter 6.2). Furthermore, the spatio-temporal variability of process parameters plays an important part. It all boils down to the systematic consideration and conceptual separation of observation, measuring and modeling scales, an area which requires more work. This field acquires a practical dimension when we bear in mind that information on average ecosystem states is often inappropriate for assessing problem situations.

Classifying landscape ecological area types of the cultural landscape always has to start with differentiating the structural characteristics of the geocomplexes and examining the processes subject to human influence. All the **process-orientated classifications** of landscape ecosystems published in recent years start by surveying and differentiating the water, material and energy balances, with land usage (an anthropogenic control factor) also being included (Bräker 2000, Duttmann 1993, Mosimann 1990, Zollinger 1988). The levels of hemeroby are often considered in order to characterize the degree of human influence and change of the ecosystems (Blume and Sukopp 1976, Bornkamm 1980, Sukopp 1972, 1976 and in East Germany Schlüter 1982). They are classified in terms of the change of the ecosystems, vegetation, their topoclimate, their water balance, their soil and sometimes also their relief. For example, Zepp (1991) presented the systematics of landscape ecological process-structure types for the southern Rhenish Bay (near Bonn). His approach integrates the respective basic hydrodynamic type (groundwater type, water logging type, flood type, etc.) and the type and intensity of the geogenic and anthropogenic influencing of the site material dynamics. This approach was further developed by Glawion (1999), who classified the area types in Germany based on land use (structure- and process-orientated features) by the type and intensity of anthropogenic influence on the natural material dynamics. In addition, the area types are characterized in a table in terms of their site-balance indicators water, nutrient and heat balance. Landscape ecological investigations with the aim of spatial differentiation are made more relevant and suitable for practical application by taking into account anthropogenically influenced and altered processes of the landscape balance.

Another approach which is orientated less towards ecological spatial units and more towards **spatially relevant ecological problems** was taken by Schreiber together with his students. The investigations mainly carried out on the basis of site theory were designed to survey ecological processes. For 20 years Schreiber carried out thorough investigations into succession development on fallow grassland, studied problems of salt build-up occurring in connection with irrigation in sub-tropical arid areas, and conducted surveys of the heat climate (growth climate) in Switzerland and the Ruhr. His contributions on the possible influence on spatial planning by landscape ecology are especially interesting (Schreiber 1985). The multidisciplinary ecosystem research with its relationships to human actions and management is focussed in the comprehensive manual of environmental sciences edited by Fränzle et al. (1997-2000). Modern methods and questions of applied landscape ecology are presented by Schneider-Sliwa et al. (1999).

Methods of biogeography and landscape ecology have also been successfully used to create planning models for the development of **environmentally sustainable tourism**. For example, in a model study for the regions of Mallorca suffering under high numbers of tourists, Schmitt (1999) developed models designed to combine the tourist industry (which is currently essential for the island's survival) with ecologically stable, natural and aesthetically pleasing landscape development which preserves natural and culturally related diversity (Figure 1.2-4). Such work not only opens up a new field of application for landscape ecology, but also provides a new research approach for tourism geography which concentrates more on areas used by tourists and less on their leisure behavior.

Approaches of landscape ecology were adopted early on by land conservation and practically implemented in landscape planning and landscape management (Buchwald and Engelhardt 1990, 1996, Langer 1970a, Olschowy 1978, see Chapter 7.3). The concept of **differentiated land use** aroused great interest (Haber 1979a, 1986). It is designed to contribute to the greater diversification of monostructurally used cultural landscapes. In the case of intensively used landscapes, it provides for about 10 percent of the area being set aside as compensation land for nature conservation. Haber's concept has been adopted and modified by several authors (Kaule 1991). A broadly based integrative ecological investigation of the landscape, such as that offered by the methods of landscape ecology, is regarded in this connection as the best condition for the scientifically based protection of biotopes and species. **Nature conservation** nowadays makes extensive use of investigative techniques from landscape ecology and holds the study of landscape ecosystems to provide the best basis for modern natural conservation, including in cultural landscapes (see Chapter 7.7)

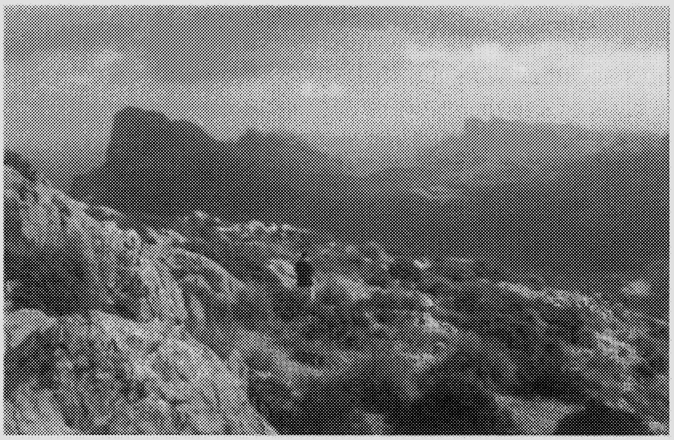

Figure 1.2-4: Landscape ecology contributes to the harmonization of economic branches such as tourism with an ecologically oriented sustainable development: Peninsula Formentor (holiday island Mallorca, Spain) (Photo: O. Bastian 1999)

1.2.6 Landscape ecology today

Nowadays, landscape ecology is an interdisciplinary, integrative science, which is geared not so much towards the holistic survey of landscape areas of various dimensions as towards certain problems in the landscape. On the one hand its tasks focus on compartments, i.e. it addresses ecological issues in the area of the soil, water, the climate, populations and biocoenosis, as well as humans in connection with their physical environment (Figure 1.2-5). At any rate, an ecological issue is understood as one involving the relationship between a living thing and its environment.

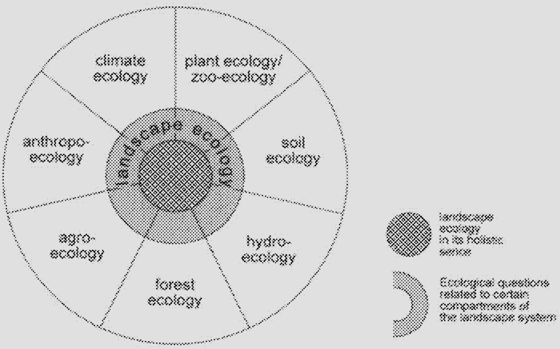

Figure 1.2-5: Landscape ecology as a frame of reference to several disciplines working on particular fields of the landscape system

On the other hand, certain ecosystems (including agricultural and forest ecosystems, aquatic ecosystems, urban/industrial ecosystems) formed more or less by human impact are tackled within the framework of landscape ecology, requiring the usage of special methods. Hence landscape ecology has been transformed from a research approach emerging in and largely confined to geography into an open, interdisciplinary sphere of knowledge and field of application (see Chapter 1.3).

1.3 Disciplinary and meta-disciplinary approaches in landscape ecology

1.3.1 Introduction

Traditions develop over a certain time at a certain place in history. Scientific disciplines and approaches to science are properly understood as historically determined traditions. Contemporary landscape ecology encompasses a whole spectrum of academic traditions with different approaches to science and education. The discussion about multidisciplinarity, interdisciplinarity, and transdisciplinarity is not new, neither is the application or the demand for the application of these approaches within landscape ecology. But how should they be understood in relation to landscape ecology? Is landscape ecology a meta-science bridging the gaps between disciplines related to landscapes? Is transdisciplinarity one approach among others in landscape ecology or is landscape ecology defined by transdisciplinarity? As the concepts of inter- and transdisciplinarity are of great importance within landscape ecology, this chapter will lay out the development of disciplinary and transcending approaches and clarify them with respect to landscape ecology. This discussion will contribute to a better understanding of the research conducted within landscape ecology. Finally, the importance of a transdisciplinary systems approach to future landscape ecology will be stressed.

1.3.2 The development of disciplinary and transcending approaches in landscape ecology

The discussions of disciplinary and transcendent approaches in landscape ecology are rooted in fundamental questions about the purpose and the role of science. Disciplinarity is a result of the historical development of science. Disciplines are historical entities and their boundaries were set in the past. By the late 1960s/early 1970s, the discussion about inter- and transdisciplinarity had started outside the field of landscape ecology as a critique of the autonomous and elite approach of science and higher education. The critique of the physician Jantsch (1970, 1972) and the philosopher of science Feyerabend (1970) were particularly influential in setting the parameters of the debate. Jantsch worked on complex systems, developed the idea of the self-organization of the universe and argued for the systems view in science and higher education. Feyerabend turned to become a critic of Karl Popper's "critical rationalism" and argued in favor of plurality of methods and approaches in science. One of the main criticisms of both was that knowledge is collected through a variety of disciplines, each fixed on the search for assumed inherent organizing principles and criteria, and valid a priori and independent of social activity. This independence from society has been understood as a critique of the missing link between science and society: disciplinarity in science was perceived as a static principle, too inflexible to cope with public demands on science. Society's innovations in knowledge, experiences, and actions outside academia were not transferred to science. Exchange among the sciences and the corresponding benefits were also lacking. A new approach was necessary to face these challenges. Jantsch (1970) postulated a general reorganization of research from discipline-oriented research through interdisciplinarity toward transdisciplinary research on complex dynamic systems.

In the field of landscape ecology the debate about inter- and transdisciplinarity started in the 1980s (Naveh 1982, 1991, Naveh and Lieberman 1984, Di Castri and Hadley 1986, Zonneveld 1988) based on Jantsch (1970) and other early initiatives in ecology in the 1970s (Bierter 1975, Young 1974). Since then, numerous landscape ecologists have dealt with multi-, pluri-, cross-, inter- and transdisciplinary concepts. Expressions and attributes like "multidisciplinary", "interdisciplinary", and "transdisciplinary" are often mentioned and used in the context of landscape ecology and landscape-related research (Barret 1992, Brandt 2000a, Décamps 2000, IALE Executive Committee 1998, Jaeger and Scheringer 1998, Leser 1997, Moss 2000, Naiman 1999, Naveh and Lieberman 1994, Reenberg et al. 1992, Trepl 1994, Zonneveld 1990, 1995 and others). However, it must be emphasized that these concepts are used rather differently by the numerous authors mentioned above. These discrepancies lead to confusion about the meaning and contents of the terms and may ultimately condemn them to be meaningless phrases or buzzwords. Clarification is needed.

In the following, six modes of scientific approaches – from mono- to transdisciplinarity – are defined and then presented in a hierarchical model of organizational principles. We rely largely on the classification schema in Jantsch (1970), as the definitions of disciplinary classes are clearest in his work. We also use Naveh and Fröhlich (1996), Naveh and Lieberman (1984,

1994) and Di Castri and Hadley (1986) referring to Jantsch (1970) when introducing the terms to landscape research.

1.3.3 Characteristics of disciplinary and meta-disciplinary approaches

Two main categories of approaches are distinguished: disciplinary versus meta-disciplinary. Mono-, multi-, pluri-, and crossdisciplinary approaches are regarded as **disciplinary approaches** because they are all more or less based on the efforts of specific disciplines. By contrast, inter- and transdisciplinarity are based on transcending disciplines and are considered as **meta-disciplinary approaches**. The complexity of approaches increases from mono- to transdisciplinarity. Apart from increasing complexity, the main difference among the several disciplinary and meta-disciplinary approaches is not the number of disciplines involved but the manner in which the cooperation among disciplines is coordinated and organized. Interdisciplinarity or transdisciplinarity does not necessarily involve a large number of disciplines. Ecologists and economists, for instance, can work together in an interdisciplinary as well as in a transdisciplinary way. This distinction makes it sometimes quite difficult to assess which theoretical approach was applied in (practical) research. One must delve deeply into the structure and organization of research to determine how the result was achieved.

In the following explanations, approaches are first illustrated using a situation involving music. This non-scientific example was chosen to make it easier to clarify the differences among the various approaches. Next, the application of the approaches to landscape ecology is discussed.

Monodisciplinarity means the solution to a problem or a question results from a single discipline. It is an approach with a one-level and one-goal organizing principle (Figure 1.3-1). "One-leveled" means that there are no relations to disciplines on other levels within the system of science. In this special case, there are not even relations to disciplines on the same level. "One-goaled" means that a given discipline is oriented towards one specific goal, looking for an answer for a certain question.

An example of this can be seen in a field outside science, music. A single musician is playing a certain piece of music on a specific instrument in a room. Practice leads to improvement in playing the instrument and interpreting the piece of music. The musician becomes an expert on his or her instrument, but is not able to play together with other musicians or to listen to them in order to learn from their ways of playing a tune.

Multidisciplinary approaches include a variety of disciplines that work simultaneously on the same subjects without building up explicit relationships between them. **Multidisciplinarity** is a grouping of disciplines with a one-level, multigoal organizing principle without cooperation or coordination among disciplines (Figure 1.3-1). "Multigoaled" here means that each of the disciplines working on the same subject has a different goal that drives its efforts. The multiple disciplines do not influence each other nor does collaboration exist.

Let us relate this concept to music: several musicians are playing in different rooms on different instruments. Each musician is playing a distinct piece composed for his or her instrument. Playing music is coincidentally the common activity but the musicians' goals in playing music are different.

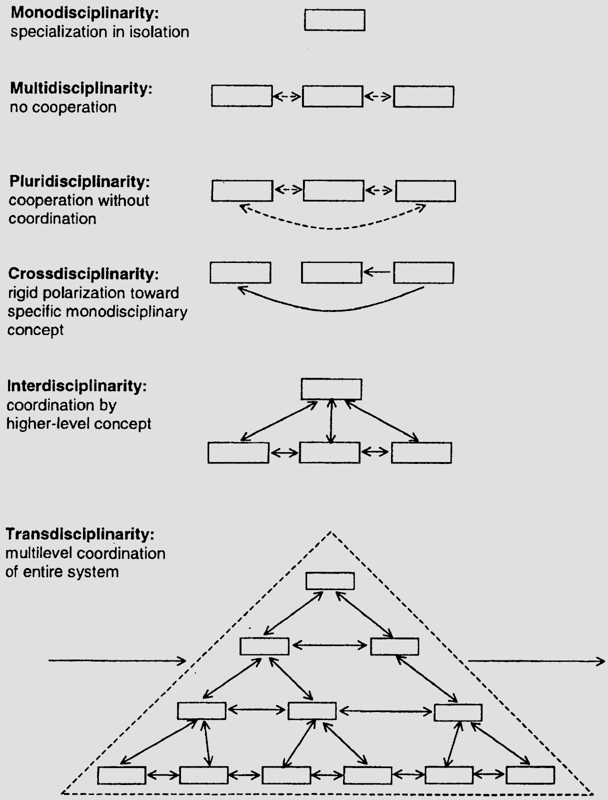

Figure 1.3-1: Schematic view over disciplinary and metadisciplinary approaches with increasing coordination and cooperation (changed after Jantsch 1970)

In multidisciplinary landscape research, the landscape itself is the common subject of all disciplines, but the reasons for conducting this research are different. In spite of monodisciplinarity, multidisciplinarity is present in landscape ecology. Landscape ecology is seen as a discipline here, dealing like other disciplines with landscape-related questions and problems.

Pluridisciplinarity refers to the purposeful grouping of disciplines at the same hierarchical level (i.e. empirical or pragmatic) side by side. Natural and human sciences are understood to be on the same level as scientific systems. They are grouped in such a way as to enhance the relationships between them. Like the multidisciplinary approach, pluridisciplinarity is a one-level multigoal, organizing principle without coordination, but with cooperation among disciplines (Figure 1.3-1). Without coordination but with cooperation means that relations and exchanges exist but they are not directed towards a common goal.

In music terms: several musicians are playing on different instruments in different rooms. Each musician is playing a distinct piece. Musicians who share expertise in an instrument - wind instruments, strings or percussion - have arranged joint practice times to exchange ideas about performing music. In this manner, each musician can make progress within his or her own subject but the musician is not trained to play one piece of music together with others.

It can be assumed that a pluridisciplinary approach is more common in landscape ecology than the others stated above. Whereas in a multidisciplinary approach there is no intended cooperation with other disciplines, in a pluridisciplinary approach to landscape ecology exchange and cooperation with other disciplines is intended. Simultaneously, benefits resulting from the efforts of other disciplines can support results of one's own work. But the benefits are not used strategically to reach a common goal, to solve a certain problem that transcends disciplines.

Crossdisciplinarity means that axioms (principles, theorems, dogmas) of one discipline are obtruded upon other disciplines at the same hierarchical level. As a result, one disciplinary axiom is used for all disciplines. The organizational principle is a one-level, one-goal approach with polarization towards a specific disciplinary goal (Figure 1.3-1).

In music terms: several musicians are playing on different instruments in different rooms. All musicians are playing the same piece by the same composer, who originally composed it just for one of the instruments. All musicians have to play their part in the tune and style of the instrument for which the piece was composed. In this manner, one instrument overwhelms all the others when the musicians play the piece together.

Projects in landscape ecology are crossdisciplinary when concepts and goals of different disciplines are reinterpreted in the light of one specific disciplinary goal. Crossdisciplinarity seems to be rather widespread within current landscape ecology, although it is seldom perceived and labeled as such. This has to do with the roots of landscape ecology in disciplines like ecology and geography. When landscape ecology is perceived as a spatial component of traditional ecological science (Ahern 1991, Bastian and Schreiber and

Opp 1999, Forman and Godron 1986, Leser 1997) a crossdisciplinary approach with its foundation in spatial ecology and ecosystem theory will always come to the fore (Moss 2000). Sometimes, crossdisciplinarity – or unidirectional interdisciplinarity, as Di Castri and Hadley (1986) have labeled it – is approached unintentionally. A crossdisciplinary attitude may often be a problem in interdisciplinary projects within landscape ecology because one tends to privilege the own discipline above others and assumes that it should guide them.

The problem of categorizing applied landscape ecological research to the disciplinary and meta-disciplinary classes can be illustrated with Leser (1997, 1999) and Finke (1996). They describe landscape ecology as a discipline, mainly based on an interdisciplinary research effort by geography, biology, and ecology. They stress the inclusion of a number of disciplines in landscape ecological research, but do not stress coordination towards a common goal among the disciplines. Additionally, the ecosystem perspective of landscape ecology dominates the disciplines included by Finke (1996), Leser (1997), as well as by Mosimann (1999). This bias is the main characteristic of crossdisciplinary, not interdisciplinary, landscape ecology.

In **interdisciplinarity**, as opposed to crossdisciplinarity and other disciplinary approaches mentioned above, a common axiom for a group of related disciplines is defined. The common axiom is defined on the next hierarchical level within the system of science and creates a certain purpose. The organizing principle is two-leveled now, multigoaled, and with coordination on the higher level. It creates a two-leveled system (Figure 1.3-1). The introduction of a second level indicates that the disciplines involved are readjusting their concepts, structures, methods and aims to create a unified system.

In music, this approach would mean that a group of musicians with string instruments (or winds or percussion) in a room are playing different parts of the same piece as a trio or quartet. They interpret the piece under the coordinating conduction of one of the musicians. Efforts have to be made to coordinate the different tunes.

Actually, some research projects that are considered interdisciplinary are de facto multi- or pluridisciplinary because no coordination on a higher level and no common goal exists. This misattribution can be attributed to the fact that some authors understand interdisciplinarity in a much broader sense than that developed by Jantsch (1970). To them, interdisciplinarity expresses any kind of cooperation among different disciplines (Trepl 1994). But the simple juxtaposition of several disciplines, such as landscape ecology, biology, ecology, geography, landscape architecture, or economy, all dealing with landscapes and loosely cooperating, does not fulfill the criteria for interdisciplinarity set by Jantsch (1970). It demands the integration of different disciplines and especially the coordination of their efforts towards a common goal. But reported examples of effective and successful interdisciplinary work within landscape ecology as defined by Jantsch (1970) are still rare.

Transdisciplinarity entails the coordination of all disciplines and subdisciplines related to the field of research. The basis for coordination is a generalized axiom and an epistemological point of view. Transdisciplinarity coordinates science, education, and innovations from society within one system. In contrast to an interdisciplinary approach, the interactions between science and education on the one hand, and society and its innovations on the other are an inherent part of the approach. Transdisciplinarity cannot cover only scientific research but must also include education and society because people and interests outside the academic world are involved. It is a multilevel and multigoal system, embracing a multitude of coordinated interdisciplinary two-level systems. On all levels multiple goals and relations exist (Figure 1.3-1). Transdisciplinarity's most basic principles are the systems approach and the awareness that relations exist among disciplines and transcend them. Coordination within the system moves toward a common goal, taking place on all levels of the system. The common systems goal steers the efforts of all academic and non-academic participants.

In music, this situation is comparable to an orchestra of musicians with different instruments playing a symphony. A conductor leads the process of practice and performance. The musicians are not always practicing together; smaller groups (e.g. winds, strings, percussion) sometimes practice on their own to prepare their contribution to the performance. The overall goal of all the musicians is the group performance of the symphony in front of an audience. Together they are creating a system that shapes a new whole, the performance of the symphony. But a well-functioning orchestra needs - besides coordination and cooperation - well educated musicians who have expertise in their instruments. The instruments as well as the musicians are subsystems and elements within the system. The relations among them are of great importance for the overall common goal.

In contemporary landscape ecology a transdisciplinary approach is an exception, but nevertheless widely discussed and demanded, above all by Naveh (1999, 2000a) and Naveh and Lieberman (1994). Several international conferences on landscape ecology and landscape research (WLO 1998, Palang et al. 2000, Tress et al. 2001) indicated that transdisciplinarity will have increasing importance for future landscape ecology. Even if transdisciplinary landscape ecology is still an exception the groundwork can be found, one example of which can be seen in the work of Luz (2000), who considers participation of local stakeholders as crucial for landscape planning and management. In his research, public awareness and stakeholder's acceptance are necessary preconditions to implement holistic and transdisciplinary landscape ecology (see Chapter 7.12).

Following Jantsch (1970), the differences among the several disciplinary and meta-disciplinary approaches can be summarized as different sorts of cooperation and coordination among disciplines, interdisciplines, and non-academic fields on varying levels and in relation to the intended goals. The distinction between the several approaches described above is thus mainly one of distinct degrees of complexity. Mono- and multidisciplinarity have the lowest degree of complexity, transdisciplinary the highest. Figure 1.3-2 shows the **hierarchical order of the different approaches** in a model. Mono-, multi-, pluri-, and crossdisciplinarity can only be identified at the lowest hierarchical level. Interdisciplinarity can be identified at two hierarchical levels, while transdisciplinarity includes all hierarchical levels.

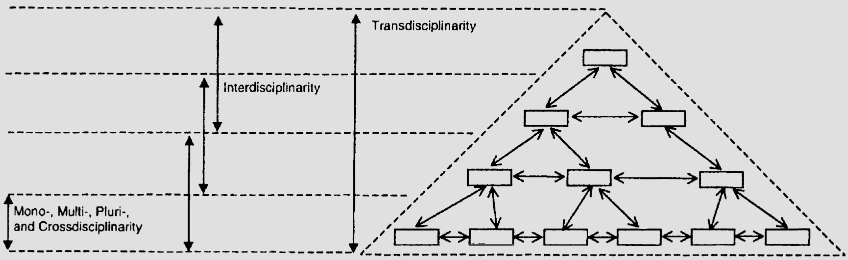

Figure 1.3-2: Hierarchical model of the organizing principles of disciplinary and meta-disciplinary approaches

1.3.4 Disciplinary and meta-disciplinary landscape ecology

As the above mentioned examples have illustrated, landscape ecological research, practice, and the demands on landscape ecology are oscillating between multidisciplinarity and transdisciplinarity. And therefore one could, in the words of Wiens (1992), ask the legitimate question: "What is landscape ecology, really?" Yet in spite of the multiplicity of concepts, Brandt (1998), Moss (2000), and others identify two main directions within current landscape ecological research, education and practice: the first is the spatially oriented field of landscape ecology, based mainly on ecology and geography and closely related fields. The second is a broad conglomerate of many disciplines, connected through the landscape as a common object of interest, rooted in different schools and traditions and with more or less coordination towards a common goal. While the first trend is oriented towards multi-, pluri-, or crossdisciplinarity, the second is oriented towards inter- or transdisciplinarity, stressing that the latter is the goal for the future. The main difference between the two directions is that in the first case knowledge of landscape ecology is only loosely linked (Hobbs 1997) because a few disciplines are working together in a more or less uncoordinated way, or work under the leadership of dominating disciplines like ecology. In the second, a broader range of disciplines works together, trying to integrate and order their knowledge in a common effort while acting as equal partners. If efforts are made towards transdisciplinarity, then even non-scientific knowledge, i.e. from stakeholders, is part of the common research effort. Accordingly, the former trend in landscape ecological research, education and practice is considered **disciplinary** landscape ecology; the latter is **meta-disciplinary landscape ecology**.

1.3.5 Positioning future landscape ecology

Now that recent landscape ecology studies can be identified as either disciplinary or meta-disciplinary the question arises as to future directions? Different concepts can be found among landscape ecologists. For Golley (1988) and Wiens (1992) the future of landscape ecology was identified and defended as a spatially oriented ecology. Hobbs (1997) stressed the lack of integration of knowledge brought together from different disciplines. This lack of integration of knowledge was also claimed by Moss (2000). In his opinion, both directions limited their ability to provide solutions at a landscape scale. The first direction reduces the applied theories, methods and the problem context to the interest of the dominating discipline. The second direction loses a transfer of knowledge and misses the development of theoretical base because of its temporal character. Landscape ecology could make itself stronger within the scientific community if it would be and act like an ordinary discipline (Moss 2000).

Another proposal is made by Brandt (1998). He concludes that both directions are necessary to the future of landscape ecology. A meta-disciplinary approach to landscape ecology must have a disciplinary basis to build on and to transcend (Décamps 2000). Meta-disciplinary landscape ecology needs disciplinary landscape ecology because of its higher level of complexity. When working on the highest level, transdisciplinarity, lower levels of complexity are always included. The complexity issue is the most challenging one for future landscape ecology and must be considered carefully in future research, education and practice as highlighted by Naveh (1999) and Naveh and Fröhlich (1996).

From the mid-1990s, it became clear that the complex environmental and related social problems could not be solved with a narrow approach to landscape ecology, relying only on knowledge from ecology, geography and closely related fields. Brandt (2000), Di Castri (1997), Hobbs (1997), Li (2000), Moss (2000), Naveh (1995) and many others stressed that complex problems could only be solved with an increasing effort to coordinate all the skills available. New knowledge is required within established disciplines and at their edges, and new ways of communication are necessary (Décamps 2000). But obviously the ongoing debate has not led to fundamental changes in the approaches applied in landscape ecology until now. Naveh (2000a) remarked that the crossing of disciplinary boundaries has not yet been reached. The development in landscape ecology has led to the designation of many specialists with subjects and skills related to landscapes. But progress in science is determined not only by analysis but also by synthesis (Brewer 1995, 1999, Mittelstrass 1993). Problems have to be seen in a larger context.

To position future landscape ecology between disciplinarity and meta-disciplinarity and to maximize the full benefits of both directions, an approach must be applied that can both solve problems and integrate knowledge instead of segregating it. To fulfill these demands simultaneously, a transdisciplinary approach based on systems view must be applied to landscape ecology.

1.3.6 The need for a transdisciplinary systems approach to landscape ecology

An approach to landscape ecology that meets the above-mentioned demands will rely on a certain understanding and perception of landscape. In a transdisciplinary approach, landscape is understood as a complex system that comprises the geo-, bio-, and noosphere subsystems. The perception of landscape is holistic; people perceive "a whole which is more than the sum of its composing parts" (Smuts 1926). This holistic systems view of ordered wholeness differs from the reductionistic and mechanistic view of nature in which complex phenomena are broken down and analyzed through their reduction, isolation and fragmentation into elementary parts.

In the 20th century, scientists in physics and biology and later in many other disciplines discovered systems of high complexity acting as integrated wholes (Capra 1996, Checkland 1986, Gräfrath et al. 1991, Jantsch 1980, Laszlo 1998). This knowledge spread and by the end of the 1930s, biologists, psychologists and ecologists had formulated what later was called **the systems view**. This is not a static, but rather a dynamic concept; it does not perceive the world as a fixed reality, but as an ever-changing phenomenon that might be unstable, uncontrollable, even chaotic (Gleick 1988, Laszlo 1987). Systems theory developed tools to handle these "unpredictabilities". Within systems theory it was also discovered that all living organisms (including the earth) have a hierarchical organization, which means that all systems consist of subsystems (Bowler 1981). This recognition reveals one of the most important characteristics of systems theory: it focuses on the connections and relationships among elements in a whole instead of looking at its separate parts. "In [the] systems paradigm the objects are seen as networks of relationships embedded in larger networks" (Oreszczyn 2000). This knowledge is essential in landscape ecology.

Transdisciplinary landscape ecology requires the integration of the geosphere with the biosphere and the noospheric human-made artifacts of the technosphere (Naveh 1991). **Landscapes consist of material and cognitive systems**. Material systems include concrete parts of the biophysical world of the geosphere and the biosphere, while cognitive systems include the mind-directed part of the noosphere. The **noosphere** is understood as the mental sphere of humans that is characterized by perception and reflection and where humans interact with the physical-material reality of geo- and biosphere (Tress and Tress 2001a). Landscapes are the visual product of this process. Naveh (1995) defined landscapes therefore as the "tangible meeting point between nature and mind". A landscape does not exist as such without relationships among elements that impact each other. **Holistic landscape research** requires an approach that bridges these scientific traditions, an approach based on transdisciplinarity and systems theory (Tress and Tress 2001a).

Figure 1.3-3: Landscape is a system of interwoven elements and not a distinct object; Taurus Mountains (Turkey) (Photo: O. Bastian 1997)

Systems are mental constructs. They can be abstract, such as a melody, a symphony, or a poem, which are more than the individual notes and words of which they are composed. They can also be concrete, such as a watch, which becomes more than its wheels and screws, functioning together for the measurement of time (Naveh 2000c). To see landscape as a system of interwoven elements and not as a distinct object has consequences for research on landscapes (Figure 1.3-3). No longer is the researcher a remote observer, but part of the landscape, part of the observed system of inquiry (Oreszczyn and Lane 2000). Thus research with a transdisciplinary systems approach will always reflect the personal views of the researchers involved.

The **central theme of landscape ecology** is defined by Naveh and Lieberman (1994) as the study of the complex totality of all landscapes on earth and the safeguarding of their integrity, health, and natural and cultural diversity. In landscape ecology attention is given not only to the natural dimensions, but also to historical, cultural, social, political, and economic aspects. Humans must be regarded as an inherent part of the system, as interacting and co-evolutionary components, and not as external factors disturbing the natural system. But as the relationship between humans and the landscape is mutual, it must be stressed that we as humans are not only part of the landscape but that the landscape is also part of us. In the course of cultural and technological evolution humans add new emerging structural and functional qualities to the natural dimensions. Together with their total environment, humans form the highest level of ecological hierarchy on a global scale, the Total Human Ecosystem (Egler 1970, Naveh 1982, Naveh and Lieberman 1994). The **Total Human Ecosystem** is the complex sum of all landscapes, interacting and integrating with human beings. It is suggested as a guiding conceptual principle for a transdisciplinary and systems-based approach to landscape ecology. Whereas the geosphere, biosphere and noosphere can be understood as subsystems of the landscape, the Total Human Ecosystem is the conceptual suprasystem (see Figures 1.3-4 and 1.3-5).

Figure 1.3-4: he Total Human Ecosystem is the complex sum of all landscape parts which humans are integrated and interact: Landscape at the Vltava river mouth to the Elbe River near Melnik (Czech Republic) (Photo: O. Bastian 1989)

The system view of landscapes combined with the Total Human Ecosystem is the main paradigm for holistic landscape ecology.

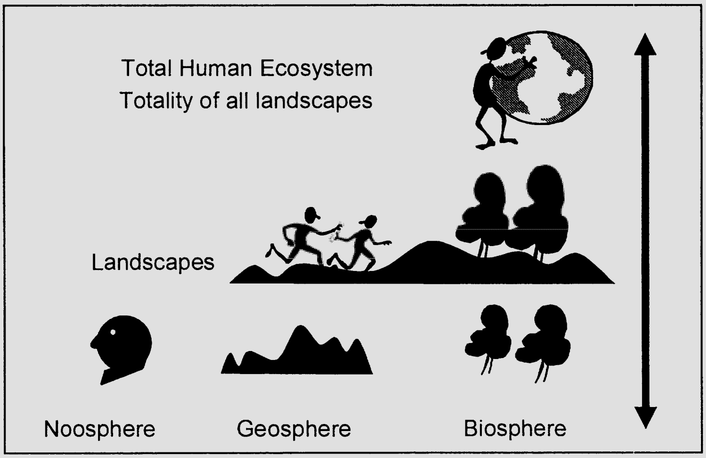

Figure 1.3-5: The Total Human Ecosystem

1.3.7 Transdisciplinary landscape ecology: towards a "post-modern science"

If landscape ecology would like to contribute to the solution of the information society's problems with environmental threats, landscape changes and sustainability, and if these problems are perceived as complex relations among elements, landscape ecology must apply transdisciplinarity. This realization brings us back to the initial question as to the role of landscape ecology in science and society. Here, we argue in favor of landscape ecology as a scientific field able to bridge the gaps among disciplines on the one hand and among science and society on the other. A transdisciplinary systemic landscape ecology as a post-modern science could deal with the complexity of life in the 21st century. It would be the end of linear and the beginning of non-linear network and systems thinking within landscape ecology. A post-modern landscape science would house innovation and tradition, creativity and knowledge, spontaneity and planning. Di Castri (1997) argues that landscape ecologists can either be committed actors or critical but marginal spectators of the game. Adopting the former requires transdisciplinary landscape ecology, which opens a constructive dialogue between science and society in relation to the landscape.

1.4 Landscape ecology in different parts of the world

1.4.1 Introduction

There are apparently many different ways of "doing landscape ecology". This diversity is evidenced from the program of recent international meetings, such as the last IALE World Congress in Snowmass, Colorado (Palang et al. 2000, Wiens and Moss 1999) and key journals, such as Landscape Ecology, and Landscape and Urban Planning. Are we in a period when there are several competing paradigms within the subject area, or is there more than one way to look at the world?

Questions about the content and character of landscape ecology are not merely academic ones, for there are evident tensions within the field. Leser (1976) provides an early account of the historical roots of landscape ecology (see Chapter 1.2). More recently, other commentators have considered the nature of the developing field for study. For example, landscape ecologists in Europe have questioned what they see as the growing dominance of the "American Tradition", which pays little regard to the deep roots of the subject in continental Europe (Bastian 2001, Haber 1996). As Antrop (2001) has shown, for example nearly 50% of the papers published in Landscape Ecology between 1987 and 1999 came from the North American study area. Although US commentators usually mention where the term comes from, and stress the fact that the European, Carl Troll, was a **bio**geographer, the implication is that ecology is the main science that underpins the field (Sanderson and Harris 2000, Turner 1989, Turner et al. 2001a). The "cultural tradition" that characterizes much European work is often ignored. Elsewhere, Moss (2000) has argued for the development of a more distinctive approach to landscape ecology in Canada. With the founding of many national IALE groups in Europe, it is likely that differences between the various approaches to landscape ecology will become apparent. This has certainly been the case in Germany, where one stimulus for the formation of a national IALE regionin 1999 was the desire to create a better platform for the German tradition.

Bastian (2002) suggests a variety of factors may be responsible for the lack of any unity in the way people approach landscape ecology, including:

- historical factors shaping the development of traditions in different countries,
- differences in the emphasis placed on the theoretical and practical aspects of the subject, and

– differences in the questions and issues faced by ecologists in different places.

This chapter explores these issues further and reports the results of a recent survey of landscape ecologists from a number of countries about the character and context of the subject area. The results provide a focus for discussion about the different approaches to landscape ecology, and the ideas that underpin its methods, concepts and theories.

1.4.2 Contrasting approaches to landscape ecology

A short questionnaire about approaches to landscape ecology was sent via e-mail to all members of five different IALE-regions, Canada, Denmark, Germany, UK and USA. Altogether 513 questionnaires were sent out and there were 286 replies, from which the data in this chapter have been reported. The results in this Chapter are based on analysis of four of the national groupings. When interpreting the data the weaknesses of surveys such as this must clearly be born in mind (Lamnek 1995). At the outset, for example, it must be noted that the survey was of IALE members, which may not be representative of landscape ecologists in general. Moreover, we have no idea about the views of those contacted who did not reply. Nevertheless, the data do provide some insights into the current "state of play" in landscape ecology.

The survey asked respondents to locate their education and their present approach to landscape ecology on a graph (Figure 1.4-1). On the graph, the y-axis picked out the spectrum between the two main sources disciplines for landscape ecology, namely the mother disciplines to landscape ecology, geography and biology/ecology (Bastian 2002). The x-axis set out the spectrum between "basic" and "applied" science. Only 5% out of the respondents had difficulties in locating their approach on the graph. The results are summarized in Figure 1.4-1, which was constructed by counting the number of respondents that placed the "center of gravity" of their area of interest in one or other of the four quadrants of the graph. The numbers of respondents in each sector of the graph by region are shown in Table 1.4-1. The size and shape of the area representing each national group indicates subjectively the spread of the answers received.

The results shown in Figure 1.4-1 suggest that there are distinctive national groups. Landscape ecology in the UK, for example, seems to be located between those of Germany and the US, in terms of their links to geography and biology/ecology. Respondents from the US group felt themselves to have a more "ecological" background. By contrast, the German respondents saw themselves as having a more "geographical" background, although it is clear from the work of Haber (1996), Bastian and Schreiber (1999) and

Beierkuhnlein et al. (2000) that a stronger biological tradition may be developing in recent years.

Table 1.4-1: Results of questionnaire survey asking landscape ecologists form four IALE-regions about their education/background. (G = geography, B/E = biology/ecology, B = basic science, A = applied science). Numbers are given in absolute and % in brackets

	G – B	G – A	B/E – B	B/E –A	Total	(%) of sent
Canada	0.0	4.8	0.0	7.2	12	(28.6)
	(0)	(40.0)	(0)	(60.0)	(100)	42
Germany	33.0	4.0	12.0	3.0	52	(51.0)
	(63.5)	(7.7)	(23.1)	(5.7)	(100)	102
UK	6.45	6.3	18.0	11.25	42	(45.3)
	(15.4)	(15.0)	(42.9)	(26.7)	(100)	95
USA	3.75	7.5	32.5	11.25	55	(20.1)
	(6.8)	(13.6)	(59.1)	(20.5)	(100)	274

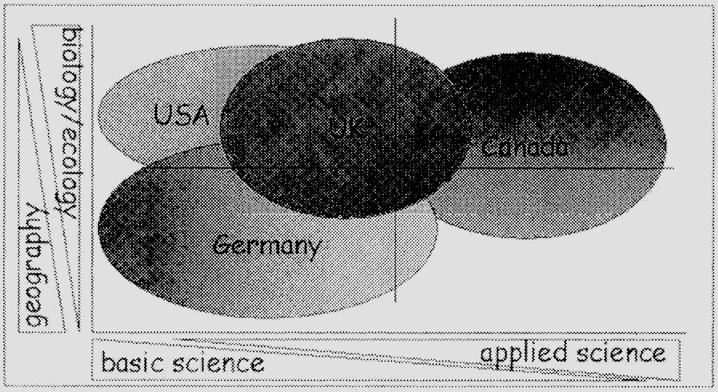

Figure 1.4-1: Summary of the results of the questionnaire to determine the background of landscape ecologists. The summary is based on the data for 151 respondents shown in Table 1.4-1 (after Potschin, in prep.)

Moss (2000) has stressed that there is no single North American approach to landscape ecology. This observation seems to be supported by the results of the survey, which placed US and Canadian respondents in different parts of the graph. The latter saw themselves more as applied scientists than those in the USA.

A second question in the survey asked the respondents to consider the disciplinary links that were appropriate for landscape ecology. Respondents were asked if they felt that landscape ecology was interdisciplinary, and to suggest what other subject contrasts might be placed alongside the y-axis of the graph. This question was designed to follow-up issues such as those identified by Moss (2000), who suggested that there is a gap between how landscape ecologists thought they should approach their research and the way it is still done by the majority of scientists (Table 1.4-2).

Table 1.4-2: Constructs in landscape ecology and their limitations to developing the problem-solving abilities of the field (from Moss 2000, modified)

Constructs in landscape ecology	Limitations to developing the problem solving abilities
Landscape ecology is a spatially oriented, sub-component of the discipline of ecology, with a firm foundation in ecosystem theory	Dominance imposed by the one discipline based upon the theory and techniques developed within that discipline. This discipline base is furthermore only relevant for a particular component of the landscape (e.g. the plant and animal community) that is fundamentally more extensive and inclusive than the biotic component at the Earth's surface.
Landscape ecology is an overarching interdisciplinary focus, which comes together at times, in various combinations to solve particular problems; that is, it is either as goal-oriented or inter- or transdisciplinary	Whereas the immediate research problem may be solved, the abilities of a particular interdisciplinary team will be lost, its reason for existing will disappear, and ist ability to transfer its knowledge to other, unrelated problem areas will be severely limited. Consequently a body of defined knowledge and a systematic theoretical framework does not develop.

Although many landscape ecologists saw themselves as working primarily within one discipline area (Figure 1.4-1), many (70%) supported an "interdisciplinary" approach. About 9% believed landscape ecology to be a mixture of geography and biology/ecology and a landscape planning, management and/or architecture discipline. A further 19% simply suggested that we needed more than the two already indicated on the axis, without being specific. Most respondents (42%) suggested that there was a need to combine the natural sciences with the environment related social sciences and economics. It was apparent, however, that there were differences between the different national groupings. The majority of US respondents, for example, interpreted "interdisciplinarity" in terms of the need for links between ecology and another science area, such as GIS, remote sensing, statistics, computer science. The extent to which respondents were arguing for a "multidisciplinary" rather than an "inter-" or "transdisciplinary" approach was unclear (for definitions and description of these terms see Chapter 1.3). It is interesting to note that only 4% of the answers from US-landscape ecologists suggested that collaboration with social scientists and economists was essential, whereas about 25% of respondents from the UK and 35% from Germany saw such a link as desirable.

The results of questionnaire survey suggest that overall landscape ecologists still see themselves as being deeply rooted in either geography or ecology/biology, but that there is a gap between current practice and the way people thought the field should develop. The results support the observations of Moss (2000) relating to the tensions between a discipline focused on a single subject area and a more interdisciplinary approach. However, the results highlight that there is little consensus as to what this multidisciplinary/interdisciplinary approach might involve. Just as there are clear differences between national groupings in relation to current approaches to landscape ecology, so clear differences emerged between national groups over the possible desirable directions of future practice. It seems unlikely, therefore, that there will in the future be any less diversity in the approaches adopted by landscape ecologists than there is at present.

1.4.3 A developing research agenda: broadening the perspective

Various commentators have attempted to review landscape ecology's research agenda from the contents of the published literature. In the early 1990s, for example, Wiens (1992), analyzed papers in "Landscape Ecology" for the period 1987-1991, and concluded that output mainly focused on the following areas:

- habitat fragmentation,
- reserve design,
- maintenance of biological diversity,
- resource management and
- sustainable development.

Figure 1.4-2: Hedgerows and greenways are one of the main issues in landscape ecology: Hedge landscape in the Bohemian Low Mountains (Czech Republic) (Photo: O. Bastian 1998)

Antrop (2001) extends this type of analysis through to 1999 and considers both mainstream landscape ecological journals and published material in a leading planning journal (Figures 1.4-2 and 1.4-3). Based on a broad analysis of 3571 concepts in Landscape Ecology, he argues that the two fields share many common concerns, the most important issues relate to land use and land cover, spatial structures and processes of change. Although the scientific concepts have important practical application, however, the links between theory and practice are often unclear.

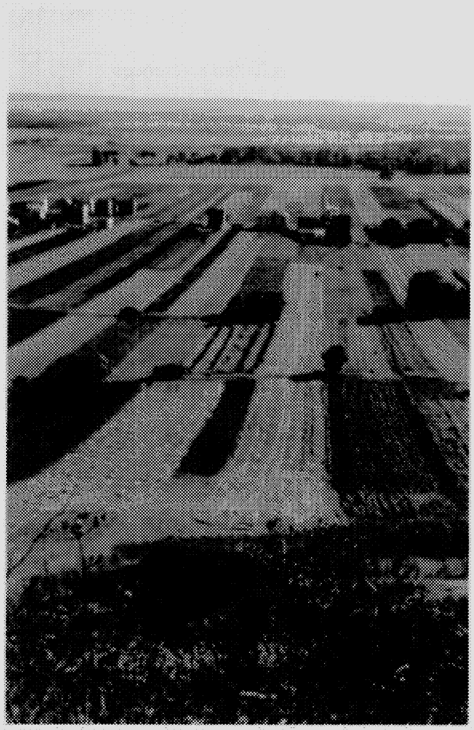

Figure 1.4-3: The consideration of space and time is a crucial principle in landscape ecology finding expression for example in landscape change studies. Traditional small-scale agricultural landscapes (here near Pinczów, Poland) are vanishing more and more (Photo: O. Bastian 1986)

Table 1.4-3 builds on the work of Antrop (2001), Bastian (2001) and others by documenting landscape ecological work relevant to those concerned with landscape planning and management. The approaches and concerns are related to the national groupings, which have been broadened to include contributions from a wider range of European countries and Australia.

Although such reviews of the contents of the landscape ecological literature can take us some way to understanding the concerns of the subject area, such analyses are, by themselves, limited. It could be argued, for example, that it is not content alone that characterizes landscape ecology but also its methodological approach, which in the "post-Rio world" of sustainable development implies a more transdisciplinary perspective (see Chapter 1.3).

Indeed one could go so far as to suggest that only by taking account of the linkages between different discipline areas does landscape ecology take research beyond what is geographical, ecological or biological. Table 1.4-4 summarizes the kinds of methodological criteria that might be used to characterize the modern landscape ecological perspective.

Table 1.4-3: Overview of key concepts and methods from a survey of recent landscape ecological publications that are of value in an applied context. The topics follow Antrop (2001). References were selected to illustrate and compare the range of concerns; the selection of papers in each category is not exhaustive (after Potschin, in prep)

concepts and methods of value to those concerned with landscape management	country	selected references
theory group (e.g. landscape ecology, sustainability, inter-/transdiscipl., equilibrium)		
- sustainable landscapes	England/ Switzerland	Haines-Young (2000), Potschin and Haines-Young (2001)
- understanding ecosystem health and integrity and self-organization of ecosystems as the basis for sustainable landscape management	USA Germany	Karr (2000) Pimentel et al (2000) Barkmann et al. (2001) Kutsch et al. (2001) Potschin and Haines-Young (2001)
- acceptance/application of landscape planning projects (transdisciplinary approach)	Germany Austria Australia	Luz (2000) Katter et al. (2000) Lefroy et al. (1991) Dilworth et al. (2000)
methods group (e.g. quantitative analysis, evaluation, quality assessment)		
- methods of analyzing of the current "state of the landscape" (base-line survey)	Germany	Richter and Kugler (1972), Leser and Klink (1988), Zepp and Müller (1999)
- monofunctional evaluation of the state of the landscape and against specific project proposals	Germany	Niemann (1977), Bastian and Schreiber (1999)
- polyfunctional evaluation methods (esp. fuzzy logic)	Germany	Grabaum (1996), Syrbe (1996)
- ecological environmental assessment	UK	Treweek (1999)
- analysis of interaction between key components or sub-systems in the landscape	Australia Switzerland	Hobbs and Saunders (1993) Waffenschmidt and Potschin (1998)
- approaches to evaluating multifunctional landscapes	Conference: European approaches	Brandt et al. (2000), Brandt and Vejre (in press) Tress et al. (2001)
change and history group (e.g. disturbance, long-term changes, landscape history)		
- understanding ecological history and landscape memory	Sweden Finland Germany	Skånes (1996a) Vuorela (2001) Konold (1996)

- landscape and disturbance	USA	Turner (1989), Turner et al. (2001a)
concepts and methods of value to those concerned with landscape management	country	selected references
application group (e.g. planning, conservation, restoration, perception/aesthetics)		
- ecosystem services and the concept of natural capital	Netherlands	De Groot (1992), De Groot et al. (2001)
	Australia	CSIRO (2001)
	UK	Turner et al. (2001b)
	USA	Costanza (2000)
- understanding of spatial processes to design a landscape by biodiversity outputs	Netherlands	Harms et al. (1993)
	Slovakia	Miklos (1988)
- green multifunctional networks (greenways)	Sweden	Mortberg and Wallentius (2000)
	USA	Lindsey (1999)
	New Zealand	Viles and Rosier (2001)
- hedgerows: network structure as an aid to redesign agricultural areas also affect of hedgerows on hydrological processes	UK	Barr and Petit (2001)
	France/UK	Baudry et al. (2000)
- nature reserve design biodiversity - (isolation/connectivity etc.)	USA	Forman (1995)
- effects of landscape fragmentation and metapopulations	USA	Forman (1995)
	Germany	Blaschke (2000), Blaschke and Petch (1999), Jaeger (2001)
	Netherlands	Opdam et al. (1995)

In the upper part of Table 1.4-4 criteria are suggested that typify what is essentially "landscape ecological" when it is viewed from a transdisciplinary perspective. The table makes the distinction between what might be terms **basic** and **applied** science, to emphasize the point that not all the criteria have to be met each time before one could say that a given paper was properly "landscape ecological". Rather, it is suggested that it is the combination of subject-related material at the landscape level with at least one or more of the methodological criteria that emphasizes the holistic aspect of the problem area investigated that marks out the contribution as belonging more properly to landscape ecology. There is no implication that every paper must involve a whole range of disciplines, but it should provide insights into how the knowledge or understanding provided fits into or solves a wider inter- or transdisciplinary problem.

Table 1.4-4: Criteria of a landscape ecological research question (LE = Criteria should be integrated in a landscape ecology as a basic science, ALE = Criteria related to applied landscape ecological research) (after Potschin, in prep.)

criteria	description	LE	ALE
inter- and/or transdisciplinary approach		X	X
(for terms see Chapter 1.3)	The outputs from landscape ecological research question should be "science" and "practitioner" related from the beginning. – Besides addressing basic science issues, landscape ecological research questions should be problem-orientated (Naveh 2000). – Including participation according to Luz (2000) and Hobbs (1997).	-	X
	If we talk about inter-/transdisciplinary approach, the environment related social science and economics must go along with nature science.	X	X
analyzing complexity	Regarding Smuts (1926) or Naveh and Lieberman (1994): "The whole is more than the sum of its parts."	X	X
teamwork	Taking sustainability into account, the landscape ecologically research question can only be answered by a team.	X	X
interaction between parameters taken into account	Analysis or take into account bi-lateral or to poly-lateral interactions of the system (Waffenschmidt and Potschin 1998).	X	X
The research question should be:			
- The "human-environment" relation is the main research focus.	These aspects should be directly or indirectly be taken into account. Does the published research present basic science (i.e. a disciplinary approach is used) or does the research question have an inter-/transdisciplinary background.	X	X
- ecology/ environment based research question		X	X
- landscape related		X	X
- take the dynamics of the system into account		X	X
- goal related		-	X
- leitbild related		-	X
- towards sustainability		X	X
- new landscape ecological methods	The combination of disciplinary based methods is one step, integrating methods are still missing in landscape ecology (esp. multicriteria evaluation, conflicting values etc.)	X	X

Antrop (2001) found that half of the papers submitted to Landscape Ecology (49%) and Landscape and Urban Planning (52%) related to the organization level below "the landscape", and it is argued here that they should therefore be regarded as "ecological studies" rather than "landscape ecological" ones.

1.4.4 It's a hard world out there!

As we attend our landscape ecological conferences and read our journals, it is easy to inhabit a rather cozy world in which we can believe that what we do is relevant and respected. However, it's a hard world out there. Consider, for example, one response received from the questionnaire survey which suggested that "...most of the research published in Landscape Ecology journals are rather too poor to publish in their own discipline. They do not fulfill the demands of the single science and so they found their niche in Landscape Ecology." The way others see us is therefore clearly very important.

If our contribution to questions about the way people manage the environment are to be valued scientifically, and find a place at the decision-maker's table, then we have to be clear and perhaps more rigorous in our thinking about what we do. The "take-home message" from the questionnaire survey and reflections on recent trends in the literature that are summarized in this chapter is that this diversity in landscape ecology is not by itself a problem, providing we view it is a broad, inter-/transdisciplinary context. Landscape ecology is not, perhaps just another discipline that aims to do more or different kinds of "geography", "biology" or "ecology". Rather, it is a movement that seeks to transcend traditional subject boundaries and understand environmental patterns and processes in a broader context, from the joint perspectives of both the social and natural sciences. Landscape ecology is a platform on which we can learn for other fields of interest and exchange and shape our own particular insights into a landscape-related problem. This position is similar to that by Décamps (2000) who, for example, has argued that activities which are "developing activities at interdisciplinary interfaces", or which aim at "linking the hard sciences to the social", must be based on "specific and precise disciplinary skills".

Through human action, our landscapes appear are changing faster than researchers can provide decision makers and practitioners with the information and understanding they need to develop appropriate strategies for sustainable development. If we, as landscape ecologists, are to provide any insights into the nature and implication of such changes, then we must go beyond discussions of diversity of subject matter and focus more clearly on what methodologically makes landscape ecology a strong and relevant subject for study.

Chapter 2

Landscape structures and processes

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2.1 Vertical landscape structure and functioning

2.1.1 Landscape spheres

Landscape is part of the uninterrupted global wrap defined as one of the axioms of geography by Neef (1956, see Chapter 1.1). At every single spot of the earth's surface landscape can be regarded as a very complex phenomenon with one vertical dimension (vertical to the surface). In this first geographical dimension the **landscape sphere** (Haase 1979) is analyzed as to its vertical differentiation and interconnections of sub-spheres and compartment spheres. The subdivision of the landscape sphere into a **natural sphere** (Naturraum) and an **anthroposphere** (Kulturraum) shows that landscape disposes of a physical body within a mental and spiritual surrounding structured by different compartment spheres (see Chapter 1.3). The **compartment spheres** are intensively influencing each other by means of functional interchange and are partly overlapping and integrating each other.

Since most of the energy coming from the sun is essential for abiotic and biotic processes within the landscape the cosmosphere can be considered as an outer layer surrounding the landscape sphere (Zonneveld 1995). The upper part of the massive inorganic mass of the earth (lithosphere) is transposed into coarse and fine material through weathering as a part of the total water on the earth (hydrosphere). Parts of the energetic and gaseous layers around the globe (atmosphere) are working on the lithosphere. All the organisms including flora (phytosphere), fauna (zoosphere) and human beings are represented by the biosphere that, on the one hand, is influencing the development of humus and soil within the pedosphere, whilst the biosphere is in-

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tegrated into the intersection of litho-, hydro- and atmosphere. On the other hand, the biosphere is depending on the whole natural environment, which in turn is structured by all natural compartment spheres. The earth's surface itself can be regarded as an epidermis structured by endogenetic and exogenetic processes forming different relief features (toposphere). The toposphere is part of the geomorphosphere as mass movement and accumulation integrating processes within the atmosphere, hydrosphere, pedosphere and biosphere are responsible for relief formation. From a natural scientist's point of view the "natural sphere" (Naturraum) can be regarded as an open system comprising the upper lithosphere, the lower part of the atmosphere and hydrosphere as well as the total pedosphere, geomorphosphere and biosphere.

Humans are not only a natural part of the biosphere but influencing the natural sub-sphere intentionally as has been explicitly referred to by Herz (1966). Hence, the so-called **anthroposphere**, like the natural sphere, can be distinguished into several compartment spheres as well, mutually influencing the natural body of the landscape by means of mental and spiritual activity of man. Human impact on the landscape sphere expresses itself in e.g. technological constructions, works of art and modified natural environment. The compartment spheres of the anthroposphere can be differentiated into the organization and structure of the society (sociosphere).

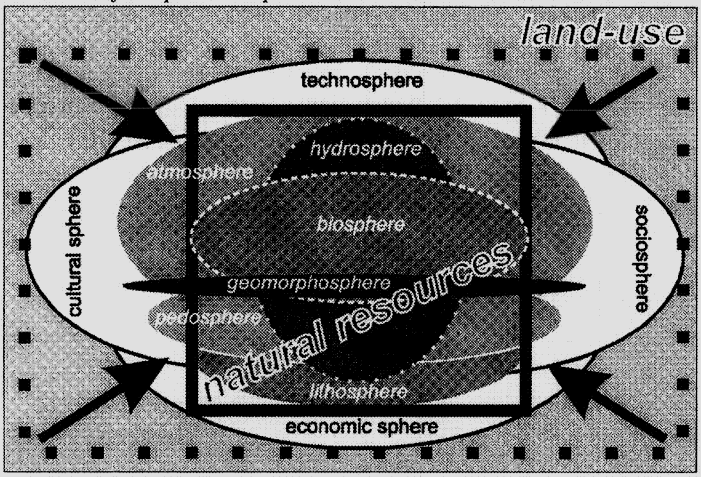
These are:

1. the cultural background which influences the social values and standards by means of tradition, religion and fashion (cultural sphere),
2. the economy and economic structure (economic sphere) defining the framework of human activity, and
3. the technical infrastructure, technology and techniques (technosphere). While social, cultural and economic spheres are non-material spheres per se the technosphere, like the natural compartment spheres, is also being represented by means of material substance (buildings, traffic, etc.).

The material part of the landscape sphere model leads to the point of drawing connections between natural resources and anthropogenetic processes within the landscape sphere. As shown in Figure 2.1-1, the natural resources comprise the compartment spheres within the natural sub-sphere; they are exploited by human society and transformed into artificial or semi-natural matters. **Land use** in the widest sense is regarded as human activity within the landscape including nature conservation, recreation, forestry, agriculture, industrial buildings, housings, roads/traffic, etc.

Land use activities and landscape development are always determined towards the current natural resource structure taking advantaging factors of the natural environment into consideration (e.g. soil fertility, groundwater storage, building ground, etc.). The use of natural resources results in a complex spatial land use structure with different types, intensities and dynamics of land use. In this sense, landscape can be defined as nature being more or less influenced by human society within which all natural components and social activities are determined by natural laws. According to this approach terms like **natural landscape** or **cultural landscape** do not make sense (Billwitz 1997).

Figure 2.1-1: Model of compartment spheres and connections between natural resources and



anthropogenetic processes of land use

Although landscape ecology does not just deal with landscape structure per se the inventory of objects and attributes often forms the basis for landscape analysis (see Chapter 3.2). The measurement of landscape processes is the attempt to characterize ecological functioning within the balance of nature.

2.1.2 Vertical landscape structure and the econ-concept

The vertical landscape structure is analyzed within the scope of microscale approaches focussed on the correlation between different structural elements. In Germany landscape ecological methodology is based upon the theoretical concept of the "homogeneous natural sphere" (Billwitz 1997) or "landscape ecological site" (Leser 1997). Actually, those sites only exist in theory. Nevertheless, landscape can hardly be analyzed without using a spatial frame for the installation of technical equipment for empirical measurements in order to transpose obtained data into a corresponding landscape unit. As far as horizontal homogeneity is concerned it has been suggested to define a **smallest landscape unit** for methodological reasons. Different terms have been introduced by several authors but these definitions are not always corresponding although following the same idea (Billwitz 1997, Jenny 1958, Klug and Lang 1983, Leser 1997, Naveh and Lieberman 1994). It is suggested to define a new term with international validity: The **econ** is a concrete part of the landscape with vertical structure of landscape components. These components are determining characteristic processes between the compartment spheres of the landscape. Thus, an econ is a small area that has been chosen out of a larger landscape unit serving as a basis for the analysis of vertical landscape structure and functioning.

In this sense, an econ is not an ecotope (see Chapter 2.2) that can be mapped and characterized within its concrete spatial extension but a representative part of it. Figure 2.1-2 shows the vertical structure within an econ as an example of a virtual forest landscape. The idea of the "econ as the smallest spatial landscape body" derives from soil science which deals with the "pedon" (Greek: soil) as a pseudo-individual of the pedosphere (Schroeder 1992).

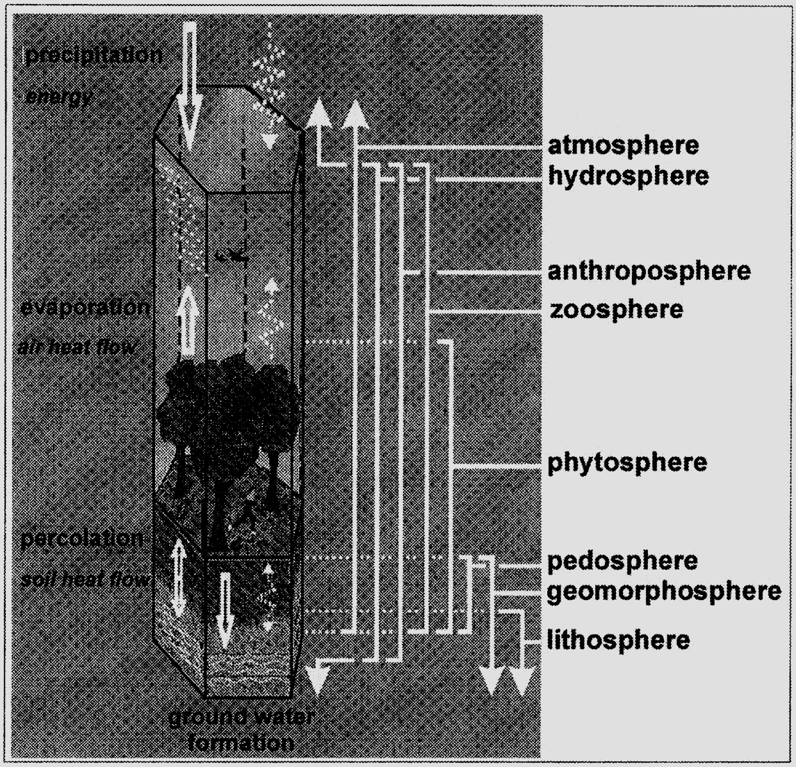


Figure 2.1-2: Landscape structure and functioning as an example of the "econ concept" using the landscape sphere model

Econs are treated as heterogeneous in the vertical dimension assuming horizontal homogeneity. In landscape ecology, unlike other natural sciences, the econ serves as the smallest spatial frame of interest. Therefore, e.g. the atomic structure of elements, the differences in particle size of substrates or the individual functioning of each organism is not subject to landscape ecology although often being a basis for landscape analyses. The question of finding and justifying **spatial homogeneity** is one of the fundamental problems in landscape ecology that is based upon the continuum character of spatial phenomena (Leser 1997). Neumeister (1979) has argued that major landscape ecological functioning is located between the upper groundwater table and the upper limit of the atmospheric layer near ground. Field investigations of vertical landscape structures and processes always take place at so-called **representative sites** or within representative econs that have been chosen to serve as an example for a larger area that comprises of many similar econs. This methodological doctrine is one of the most important agreements within landscape ecological approaches (Mosimann 1984a). However, it is not free from subjectivity because of the arbitrary choice of criteria for representativeness also known from plant-sociological approaches.

The vertical landscape structure is analyzed by means of the **complex site analysis** within the frame of the "landscape ecological complex analysis" (Mosimann 1984b) analyzing processes that link the different structural layers (see Chapter 3.4). Although the methodical principle of random site delineation has recently been criticized especially due to mathematical or statistical routines of analyses, there is no actual alternative. Accidental or regular interval methods are to be refused because of high expenditure of work, ignorance of details and fatal abstraction from landscape reality (Billwitz (2000). Landscape ecological research therefore cannot claim objectivity when it comes to field analyses.

2.1.3 The landscape complexes

The schematic differentiation of the econ due to the sphere model leads to a theoretical abstraction. Following a systems approach (Chorley and Kennedy 1971) reality is reduced to a system that can be described by means of defining **landscape complexes** as an arrangement of landscape components. Figure 2.1-3 shows the vertical structure of natural landscape components and its landscape elements within a landscape complex. It can be seen that the natural sphere and its compartment spheres are forming the background for the vertical structure of landscape complexes. In this sense the landscape complexes are the main geographical objects of landscape ecology.

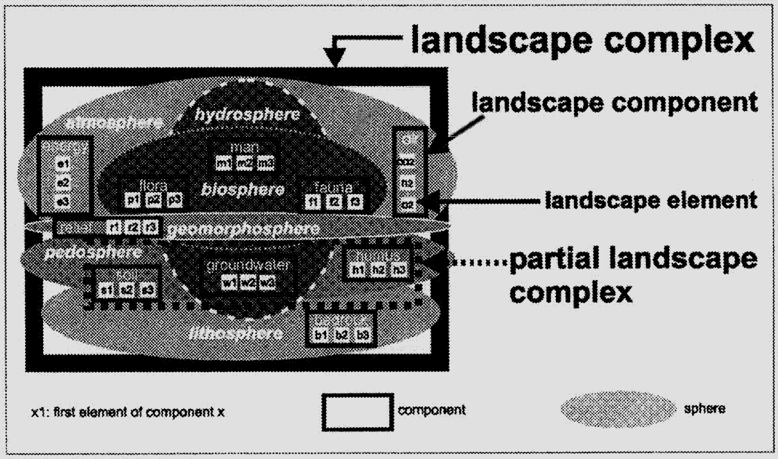


Figure 2.1-3: Model of natural compartment spheres representing a system of a landscape complex with its partial landscape complexes, landscape components and landscape elements

Partial landscape complexes consist of components and their elements of one (or few) landscape spheres. The main technical problem of vertical landscape structure analysis is based on the multitude of landscape elements and the complexity of landscape components as shown in Figure 2.1-3. For this reason the object of analysis is usually being simplified to a **layer model** abstracting the real landscape (Klug and Lang 1983). Figure 2.1-4 represents one of the most common model types that are used to express the investigation concept. It shows the landscape components as layers which are vertically combined through major groups of landscape processes. Richter (1968) has demonstrated that the soil as one of the landscape components within the layer model is functioning on a very high integration level. **Main landscape ecological features** have therefore been distinguished as layers where many important ecological processes converge.

2.1.4 Landscape ecological processes

According to different approaches of landscape ecological investigations (see Chapter 1.4), the abstraction of the system being analyzed varies from a very low to a very detailed resolution. As shown in Figure 2.1-5 vertical landscape processes can be demonstrated as functional interfaces between landscape components of different compartment spheres by **modeling hydrological functioning** within the vertical landscape structure. The water system represents a strong coupling between climate and hydrological processes on the surface as well as within soil. Many important partial processes can be found within the different vegetation layers of the phytosphere, which all in all influences intensity and amount of infiltration rates at the ground surface. The unsaturated soil-water-system is functioning as a complex motor for many vertical up- and downwards oriented processes. As a whole, the hydrosphere is of extraordinary importance for landscape ecological functioning (see Chapter 2.7). Due to the complex processes of matter and energy transformation in landscapes, special attention is paid to the water as an essential element and a mobile agent which is the main transport medium at least in temperate climates. Over and above that, water is the basis for socio-cultural and economic development and serves as a fundamental element for industrial and technological production (Wohlrab et al. 1992).

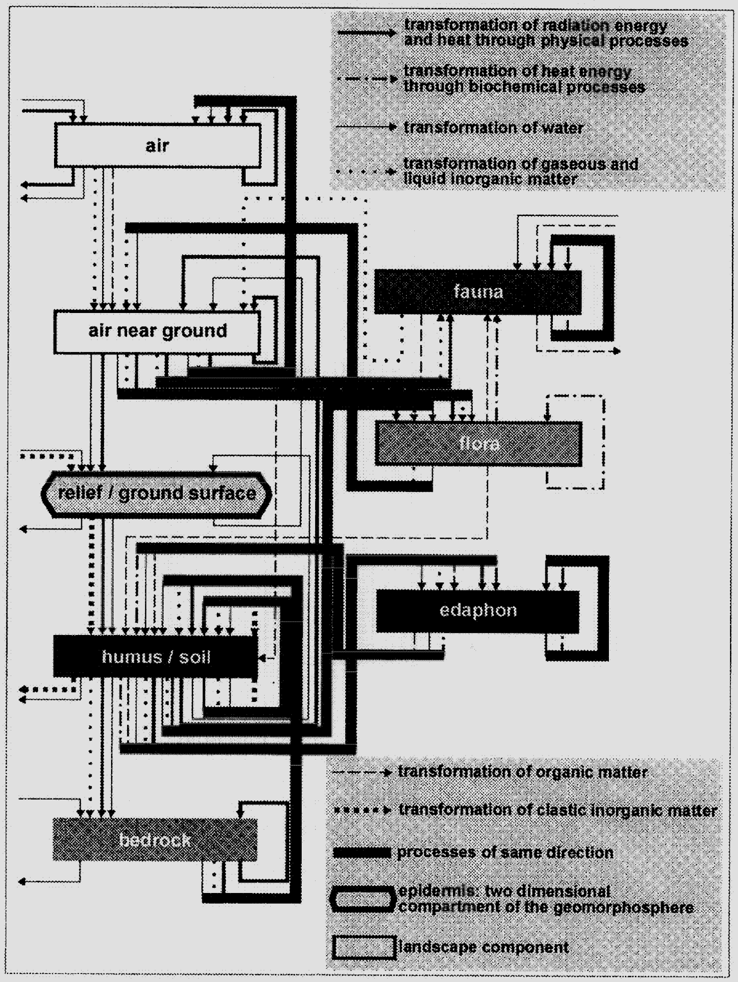


Figure 2.1-4: Model of vertical landscape structure and processes (after Richter 1968, modified)

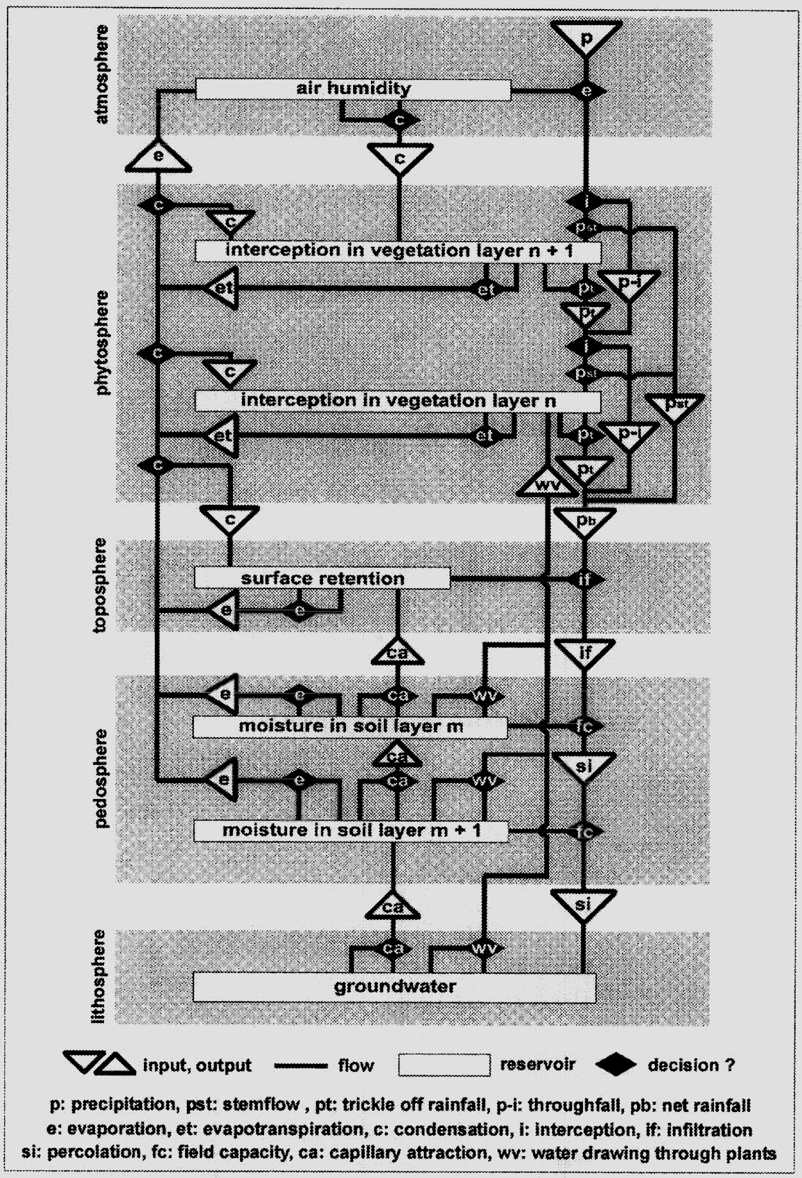


Figure 2.1-5: Vertical landscape functioning as an example of a water balance model (after Klug and Lang 1983, modified)

Landscape functioning can be regarded as a highly complex reciprocity of different primary processes. However, the analysis of those landscape ecological processes is not easy; landscape functioning is currently investigated through measurements of primary processes within the balance of energy, water and matter fluxes. Landscape ecological processes are to be examined as a combination of different primary processes measuring major elements within a process cycle, calculating immeasurable elements and balancing or synthesizing specific integral processes. Since balancing of landscape ecological processes is important for the understanding of landscape functions, process analysis always deals with quantification that is bound to extensive measurements. As Neef (1967) stated landscape ecology deals with processes within the **landscape balance**. This implies anthropogenic as well as natural processes. The processes that determine energy, water and matter fluxes are of great importance for the knowledge of interactions between the natural sphere and the anthroposphere. Consequently, technical processes are part of the landscape functioning. According to Richter (1979) and Neumeister (1979) the vertical landscape functioning is based upon special attributes of **three major layers within the natural sphere**. These layers are influenced by the intense overlapping of all compartment spheres and form a kind of permeable boundary sphere (Figure 2.1-6). Moreover, this zone is characterized by specific compensation, buffer and regulation capacities that are responsible for the balance of landscape during different periods of environmental stress (e.g. air pollution), and natural oscillation (e.g. drought) or spontaneous peaks (e.g. cloud bursts). Theoretically, major landscape ecological layers can be defined in their vertical extension and grouped into **sub-layers or horizons** of homogeneous microspheres.

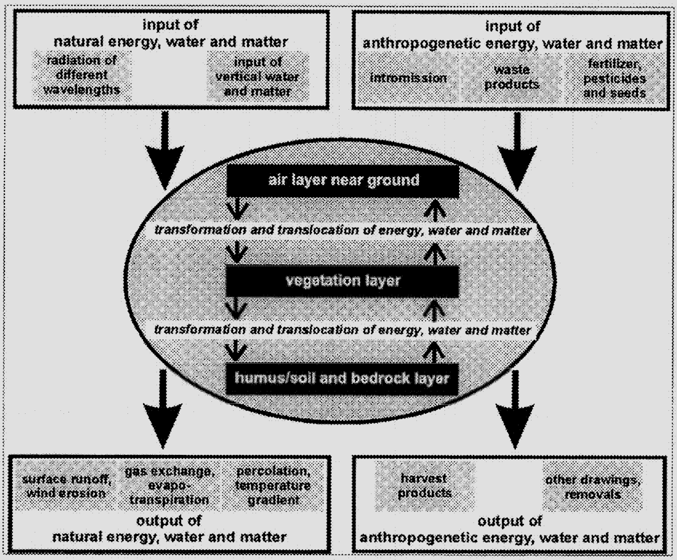


Figure 2.1-6: Vertical landscape structure and functioning within the major layers of the natural sphere including human activity (after Neumeister 1988, modified

The vertical landscape structure and functioning is to be regarded as a spatial and temporal synthesis of hydrological and atmospheric attributes; they are immobile but process influencing substances and inert variables aggregated within the different layers (Billwitz 1997).

The extrapolation of vertical structure and functioning from the first geographical dimension into a spatial unit leads to another fundamental question of landscape ecology: How can those results from the vertical dimension be validated concerning their transposition within mapable boarders? This problem is part of the **regionalization** theory that comprises space and time scale variability of landscape structure, functioning and dynamics.

2.2 Landscape complexes

2.2.1 Introduction

The landscape sphere can be considered as a system in which we regard **landscape complexes** on a high level of integration. From a high level of abstraction these landscape complexes can be analyzed within a landscape model in which landscape is reduced referring to methodological objectives being applied (Figure 2.2-1). But where, in fact, do we find landscape complexes? And how can they be differentiated and delineated?

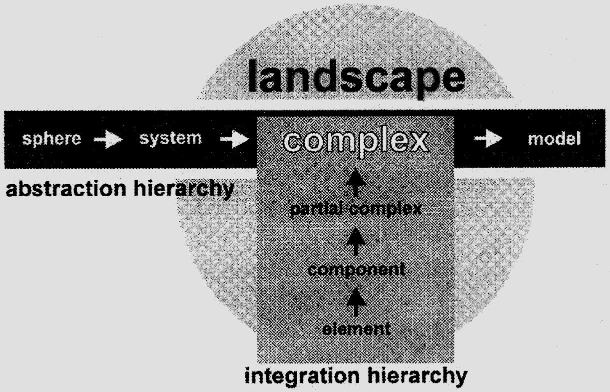


Figure 2.2-1: Landscape complex as a theoretical interface within the abstraction and integration hierarchy

The spatial arrangement of these systems will become of additional interest on the horizontal level on which landscape is differentiated according to its spatial heterogeneity. The heterogeneous compositions of different landscape complexes form a higher level of **complexity** as a fundamental part of the **hierarchy concept** (Farina 1998). In landscape ecology those complex systems representing the landscape sphere are defined as **ecosystems**. This definition of ecosystems differs from that of Chapin (2001) mentioned and discussed in Chapter 1.1.2 as well as to that of Klink (see Chapter 1.2).

It has already been mentioned that the landscape sphere with its qualitative and quantitative attributes of landscape complexes is spatially changing more or less continuously or discontinuously from every single spot to another. According to the existence of boundary spheres or **ecotones** (see Chapters 2.3 and 2.5) representing correlative attributes at the same time the landscape sphere is structured into a distinct horizontal mosaic of spatial units (Billwitz 1997).

In reality, every single local spot at the earth's surface is different from any other, but more similar to any spot in its particular surrounding than to another situated in a distance. Following the econ concept (see Chapter 2.1) the complexity of the landscape is reduced to a horizontal frame in which heterogeneity is not existent per definition. Landscape classification is one example of a hierarchical framework, moving from different spatial landscape ecological units across others. Looking at complexity as an intrinsic attribute of landscape the hierarchy paradigm explains how the different components localized at a certain scale are in contact with other components visible at different scales of resolution (Farina 1998). From the **theory of spatial geographical dimensions** (Neef 1967) we can draw methodological connections between reality, landscape sphere and ecosystems on a hierarchical level.

scales	temporal dimensions	landscape processes	temporal process persistence	examples
giga scale	evolutionary dimension	landscape genesis	> 10.000 years	geological periods (quaternary)
mega scale	sustained dimension		~ 1.000 - 10.000 years	climatic periods (ice age)
macro scale	long-term dimension	landscape dynamics	~ 100 - 1.000 years	historical periods (Middle Ages)
meso scale	medium-term dimension		~ 1 - 100 years	biological periods (forest development)
micro scale	short-term dimension	landscape functioning	~ weeks - months	seasons (ground water variability)
nano scale	immediate dimension		~ seconds - days	events (precipitation)

Figure 2.2-2: Temporal dimensions of landscape processes

Thus, landscape complexes can be characterized by their structures and processes on different **spatial scales** as well as on different **temporal scales**. Basic physical-mechanical, chemical or biological processes often determine landscape functioning on a short-term scale compared to its corresponding secondary processes. From the composition of characteristic process attributes on each temporal scale landscape complexes have to be defined by four-dimensional (spatial-temporal) landscape features. Thus, we are dealing with a **temporal hierarchy of processes** (Figure 2.2-2). On a lower level of integration primary processes basically determine landscape functioning within their short-term action. On a high level of integration linked processes determine a comparative long-term landscape genesis. According to Billwitz (1997) we can distinguish between **landscape functioning** to be considered as process synthesis on a lower temporal scale, **landscape dynamics** to be regarded as process synthesis on a mediate temporal scale and **landscape genesis** representing the higher temporal scale of process synthesis (Figure 2.2-2, see Chapter 7.2.3).

It can be summarized that landscape complexes are regarded as a theoretical abstraction integrating spatial and temporal attributes. From the fact that different landscape ecological processes are determined within different time spans spatial dimensions are correlated with characteristic processes on the temporal dimension (Neumeister 1988).

2.2.2 Topological dimension and the ecotope concept

Landscape complexes are analyzed due to their **horizontal complexity** of spatial structures and spatial-temporal processes within the landscape. As shown by means of vertical landscape structures the differentiation of the complexity of spatial structures combined through temporal processes is a methodological problem as well.

Numerous terms have been introduced to define landscape complexes for small areas[1]. They are often characteristic features of the landscape mosaic that are used to classify the continuum of the global wrap arbitrarily into meaningful classes according to key properties and objectives applied (Skånes 1996b). Several authors (e.g. Leser 1997) have given surveys of the development of those different terms to define landscape complexes. The term "ecotope" has been introduced by Tansley (1935), and has been adopted as "Ökotop" by Troll (1950). In recent publications an additional source of confusion is included in that definitions, although partly overlapping, are often used with specific implications within different fields:

[1] It has to be mentioned, that there is a completely opposed understanding of "small scale" and "large scale" in German and English or American literature: German landscape ecologists and geographers use the term “scale” in terms of cartographers: So 1:100,000 is a smaller scale than 1:10,000. So **small scale** connotes to a **large area** and vice versa. English and American ecologists use the scale terms contrarily: A small scale is coupled to a small area; a large scale to a large area. For a consistent understanding we will adopt to the English and American scientific community.

- "ecotope as an ecologically homogeneous tract of land at the scale level being considered" (Zonneveld 1989),
- "ecotope as fundamental process unit of the landscape" (Mosimann 1990),
- "ecotope as the smallest ecological land unit relevant in landscape ecology, with relative homogeneity regarding vegetation structure" (Klijn and de Haes 1994),
- "ecotope as a concrete above-organismic holon" (Naveh and Lieberman 1994),
- "ecotope = biotope" (Forman 1995),
- "landscape element as relatively homogeneous unit recognized in a mosaic on any scale" (Forman 1995),
- "topes as spatial representatives of related systems within the topological dimension" (Billwitz 1997),
- "ecotopes as spatial manifestation of related systems with similar fluxes of matter and energy" (Leser 1997), and
- "ecotope as hierarchical functional classification of the landscape" (Farina 1998).

Following current definitions in landscape ecology and integrating the econ concept an **ecotope** (Greek "topos": locality) is defined as a spatial manifestation of different econs of the same structure and spatial functionality connected with each other. Ecotopes represent the landscape sphere and its related systems of landscape complexes (**ecosystems**) within the topological dimension. Processes of vertical landscape functioning are analyzed within an econ that is defined as the spatial representative of the ecotope.

After Leser (1997) the **topological dimension** has a methodological significance in landscape ecology because

a) scientific concepts are based upon the "idea of ecological functioning on the spot" (within an econ),
b) the ecotope is the spatial basis for superior landscape ecological functioning,
c) landscape ecological processes can be analyzed and quantified by means of measurement techniques visible at a glance, and
d) functional connections of landscape elements and landscape components are recordable.

Furthermore, the ecotope is the fundamental spatial unit representing its ecosystem functioning on the basis of lateral range of ecological processes (e.g. interflow, groundwater mobility near surface, cold air flow, etc., Figure 2.2-3) and vertical process homogeneity (precipitation, percolation, etc.). The topological dimension is not just a filter for methodical and technical field investigations according to the econ concept, but also the spatial reference for field decisions in applied landscape ecology.

Ecotopes as concrete spatial landscape units can be mapped using classified structural landscape elements, landscape components or partial complexes that can be recognized during the field investigation. According to those auspicious selections of **criteria of representativeness**, ecotopes can vary in size, content etc. Unfortunately, landscape ecological methodology thus has to be characterized as a random principle, which enables the researcher to cope with the infinity of heterogeneity within the landscape. Results of ecotope mapping may differ considerably.

Figure 2.2-3: In the Moritzburg Hill Area (Saxony, Germany) the differences between the ecotopes on the hills and in the hollows are obvious by the land use (wood/arable fields or meadows) (Photo: O. Bastian 1997)

Moreover, the ecotope concept is of extraordinary importance in landscape ecology because the whole methodical procedure of landscape analysis within the topological dimension is based upon them (see Chapter 3.4).

Derived from this landscape ecological definition of the ecotope terms like biotope (phytotope, zootope), pedotope, hydrotope, etc. can be used to distinguish smallest spatial units on the basis of partial landscape complexes. Compared with the ecotope they are of lower complexity. Within the ecotope all topes, which represent partial landscape complexes are overlapping and form a higher information level.

The spatial topological arrangement within the landscape is analyzed by mapping horizontal structures of landscape complexes using attributes of partial landscape complexes. E.g. vertical vegetation structure, plant species composition and abundance etc. classified as vegetation types in combination with classified relief features (exposure, inclination, curvature etc.), land use types and other features can be used for differentiating basic landscape units. Based upon this synthetic spatial frame process attributes, properties of the fauna and further detailed structural characteristics are extrapolated from single econs to their corresponding ecotopes.

All in all, in the topological dimension landscape complexes are described by means of ecotopes, in their turn characterized by basic vertical structures and processes (see Chapter 2.1). In the topological dimension results from landscape analyses can be combined for a characterization of spatial landscape functioning. Lateral process directions and quantitative fluxes of energy and matter can be drawn from the econ-based results. The classification of ecotopes leads to **ecotope types** that are used to represent landscape complexes in their spatial arrangement (Figure 2.2-4). Ecotope types are diversely defined according to different landscape ecological approaches. It can be summarized that current landscape ecological mapping approaches follow those principles of landscape characterization; examples are given in Chapter 6.1.

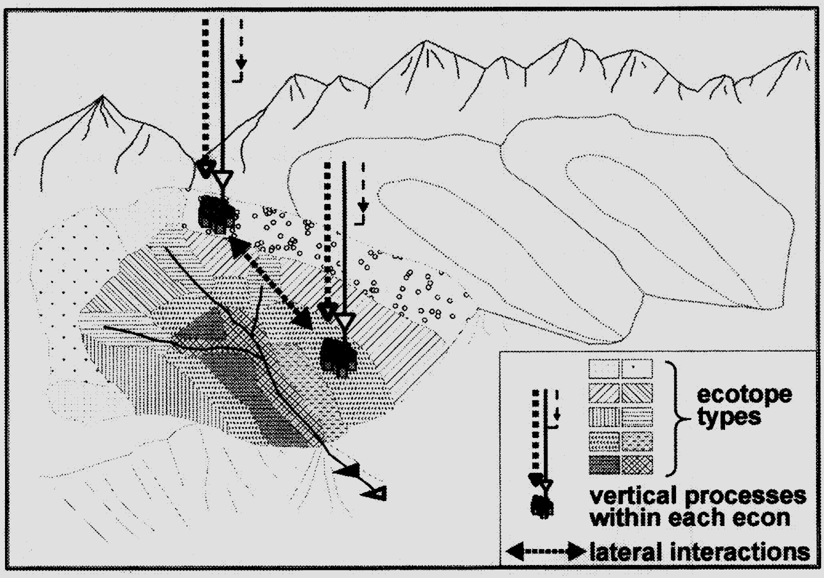


Figure 2.2-4: Scheme of a spatial mosaic of ecotopes within a small mountainous catchment area (after Leser 1997, modified)

The ecotope concept is strictly combined with landscape reality and derives its methodical advantages from the econ concept. Still, there are theoretical problems bound to the complexity of the landscape. Over and above that, the choice of landscape elements that have to be analyzed, duration of measurements, and combination of results are further difficulties in the scope of describing and quantifying landscape functioning (Leser 1997).

2.2.3 Landscape complexes of the chorological dimension

Landscape complexes of larger spatial extension can be regarded as mosaics of ecotopes. This spatial arrangement of ecotopes is analyzed as to structure and functioning of larger landscape units assembled from heterogeneous landscape mosaics. This theoretical abstraction takes place in the **chorological dimension** (Greek "choros": group) where landscape complexes are described as **ecochores**. Additionally, those heterogeneous compositions of landscape units can be aggregated on different levels of abstraction resulting in different sub-dimensions within the chorological dimension (nano-, micro-, meso-, macro-ecochores, see Figure 2.2-7). Within the chorological dimension we leave the concept of homogeneity that has been used to define ecotopes (Neef 1963). The new concept of homogeneity on the chorological level deals with internal heterogeneity reduced to new information, which is defined as homogeneous on a higher level of abstraction (Herz 1973). This theoretical **transition of emergence** has already been conducted to dispose of spatial heterogeneity by means of aggregating numerous econs defining a higher level of abstraction within an ecotope. The aggregation of a mosaic of ecotopes that are dealt with in the topological dimension leads to a new spatial unit defined as an ecochore. According to Haase (1967) it is not possible to define absolute criteria of homogeneity; thus ecochores will always be a result of random decisions to which ecological attributes have been adopted as a premise.

As shown in Figure 2.2-5 topological units are aggregated within small catchment areas that are analyzed according to their chorological arrangement within a system of a valley.

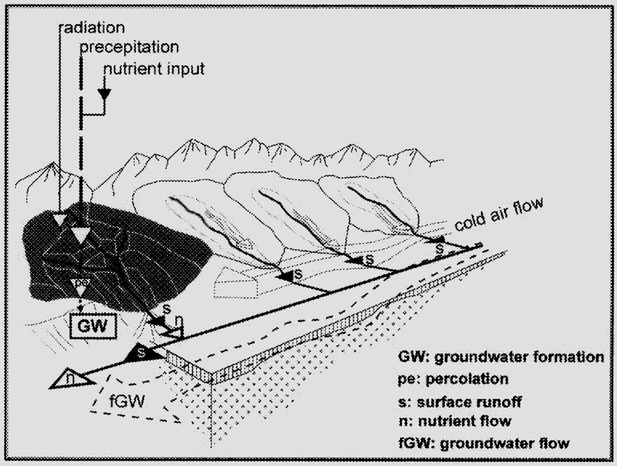


Figure 2.2-5: Scheme of processes within small mountainous catchment areas representing a mosaic of ecochores within a valley system (after Leser 1997, modified)

All these **ecotope mosaics** assembled within several catchment areas follow the same landscape ecological functioning principle in the topological dimension. The processes that determine the functioning of the whole valley system find their origin in the single ecotopes represented by an econ. Two different levels of abstraction have been conducted: ecotopes shown in Figure 2.2-4 are reduced to an ecochore that is functioning as a separate landscape unit. Furthermore, different ecochores are functioning within a valley system. On both levels of abstraction different ecological structures and processes are conceived as characterized by the appearance at different spatial dimensions and by forming a new and unpredictable character through the rearrangement of pre-existent entities. E.g., the process of cold air-flow finds its origin within the single ecotopes where cold air is produced. The cold air stream through a catchment area is determined by the same basic process of cold air production within different ecotopes and therefore cold air-flow within each catchment is a new emerging chorological process on a higher spatial level. The same **principle of emergence** is found on one higher level of abstraction where the cold air stream within the valley is determined by the outlet of cold air from different catchment areas.

It is undeniable that the fundamental historical development of German landscape ecology is based upon the principle of the **chorological structure analysis** (Billwitz and Mehnert 1992, Haase et al. 1991). This static inventory of physical properties of the landscape can be explained by defining spatial units as a basis of natural resources evaluation for land use patterns. Within this frame, there always was and still is a close application basis. If landscape complexes within the chorological dimension are attaining to be of interest for applied sciences, it will have to be dealt with the recent problem: What are the fundamental emerging attributes of the ecochores in analysis?

Richter (1968) tried to solve this methodological problem of analyzing such heterogeneous landscape complexes of larger spatial extent by modeling. Several authors had similar approaches, but could not solve the problem of missing data for large areas (Leser 1972, Schmidt 1978). As Leser (1997) has summarized the way of using methods and techniques applied within the topological dimension and the aggregation of those results into a higher organization structure of chorological dimension cannot succeed; chorological analysis needs its own methodological principle. Since the possibilities in remote sensing have developed rapidly there are a lot of technical opportunities for chorological field investigations. Thus, landscape complexes are currently synthesized in the chorological dimension by aggregating attributes from topological investigations. This empirical and **inductive way** leads to satisfactory results within small chorological areas. For an example of a process-orientated synthesis of ecochores from the basic topological investigation, see Chapter 6.1.

2.2.4 Landscape complexes of higher geographical dimension

Landscape complexes of higher geographical dimension are represented by the theoretical concept of **ecoregions** and **ecozones**. Concerning their spatial extension we leave the methodological level of ecotopes and ecochores completely. Starting with the regional dimension we deal with a synthesis of ecoregions. Processes that correspond between the single ecoregions origin within the ecochores transposed through the spatial level of ecochore mosaics. So water and matter fluxes in streams and rivers evolving from continental topography and energy fluxes according to wind systems resulting from the spatial arrangement of continents and oceans are going to be described (Leser 1997).

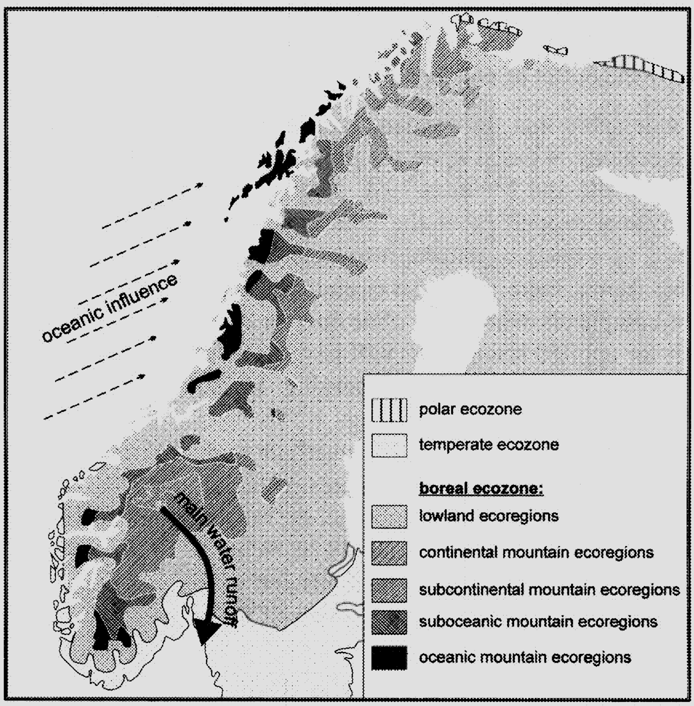


Figure 2.2-6: Ecoregions of the Scandes as an example of atmospheric dynamics, main climatic and hydrological processes and mountain relief patterns

As an example, ecoregions of Scandinavia are demonstrated in Figure 2.2-6 showing a spatial mosaic of different climatically defined regions.

The methodological principle within the regional dimension is deductive. Large areas are divided into partial units by means of characterizing prior attributes that are defined to be of interest. Recently, techniques being adopted for spatial analyses are principally based upon remote sensing (see Chapter 6.3).

The landscape ecological approach within the regional dimension is based upon the belief that differences in geographical positions determine abundance and change of attributes as has been stated by Lautensach (1952). Following this principle which is associated with the idea of an existing "natural system of the earth" being responsible for the structures and processes of the landscape in fact being found, we will have to deal with the integration and interference of **hypsometrical**, **maritime-continental**, **polar-equatorial** and **paleo-geographical changes of attributes**. The mosaic of ecoregions results from those attributes. According to Aurada (1987) ecoregions can be characterized as large landscape units determined by global position, with planetary processes as sub-systems of larger landscape units (ecozones), but autonomous with regard to internal processes. Landscape complexes within the regional dimension have been mapped e.g. for the United States by Bailey (1996), for East Germany by Billwitz (1997), and for Norway by Moen (1999).

The **zonal dimension** deals with landscape complexes that build up the global wrap by means of **ecozones**. Within this spatial geographical dimension the globe is differentiated due to telluric and solar influences resulting in processes that are based upon the distribution of land-masses and oceans. Those processes emerging on this high level of abstraction are of primary meteorological nature and can be illustrated by means of the global climatic circulation theory. Within such large areas distinct ecological assemblages are expected to occur. Climatic zonation is the fundamental spatial frame for the characterization of ecozones. Nevertheless, ecozones have usually been mapped according to structural attributes (Alexeev and Golubev 2000, Müller-Hohenstein 1979, Walter and Breckle 1983-1994). According to Schultz (2000) ecozones (polar, boreal, temperate, subtropical and tropical) are defined as **geo-zonal ecosystems** which are classified by means of qualitative attributes such as soil formation, vegetation structure and landforms as well as quantitative attributes such as integrative attributes of energy and matter status like biomass and primary/secondary production. Landscape ecological attributes are assigned by means of average balances.

As far as the whole globe is concerned we deal with the spatial arrangement of ecozones regarded as highest spatial units within the global wrap. Landscape ecological research on this highest level of abstraction is represented by the **global dimension**. It has to be added that this dimension is not of superior importance in landscape ecology.

2.2.5 Landscape complexes of different dimensions

It can be concluded that **landscape complexes** are of great importance as methodological fundamentals in landscape ecology. Figure 2.2-7 gives a schedule of the basic theoretical principles dealt with on different **spatial dimensions**. Derived from the theory of geographical dimensions landscape complexes are presented in a hierarchical order combined with a proposal for corresponding scale terms. In combination with Figure 2.2-2 characteristic methodological features of landscape ecological investigations can be summarized as follows: In the **sub-topological dimension** processes are analyzed as to vertical landscape structure and functioning; in the **topological dimension** vertical structures and processes are of main interest, but ecotope mosaics are analyzed according to their spatial arrangement and functional interaction. On both levels immediate and short-term processes are of interest. Moving from the detailed analysis within the topological dimension across the **chorological dimension** into higher dimensions the attributes regarded become of interest on the level of **temporal dimensions**.

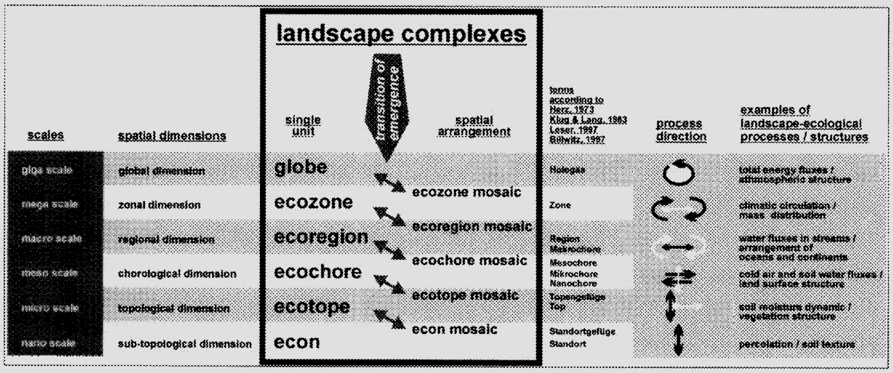


Figure 2.2-7: Landscape complexes and transition of emergence in different spatial dimensions (scales); black arrows dominant, white arrows subordinate.

This approach is adopted to several spatial levels of abstraction where landscape complexes are defined as **spatial representatives of the ecosystems**, on their turn conceived as a simplification of the landscape sphere. Since the ecotope concept is just a theoretical frame to split up the complexity within the landscape ecochores, landscape units of higher spatial dimension have to be handled on the same pragmatic background.

2.3 Landscape elements

2.3.1 Introduction

Landscapes are composed of objects, units or elements of different nature. Interactions between them create a non-random organization in aggregates and patterns. Such patterns emerge at related spatial and temporal scales.

Functional qualities of landscape elements themselves are assigned to storage and transformation. Transport, storage and transformation are the major functional categories in ecological systems. They can be related to almost all ecological compartments and qualities. The quality and identity of landscape elements is thus determined by their spatial and temporal dimension and by their integration into the flow of energy, matter and information within a larger and more complex landscape matrix. The spatial organization of elements and their temporal performance reflects the functional interrelations that exist in a certain landscape. Area, form, distribution, age, longevity, and seasonal rhythm of landscape elements are helpful **parameters to characterize** them. These parameters are easy to detect or to measure. Their relations to neighboring elements of a different kind and the connectivity or fragmentation of elements of the same type will add other important information.

Distinct landscape elements can be observed at various scales, degrees of complexity and **levels of organization**. The term "level of organization" is based on works of Egler (1942) and Novikoff (1945), who originally proposed "integrative levels" of biotic systems. Their ideas were refined and integrated into a hierarchical system of natural organization by Allen and Starr (1982) and subsequently by O'Neill et al. (1986, 1989). Levels of organization reach from the cell, the tissue, the organ to the biome or the biosphere. However, only some levels are relevant in landscape ecology and can be used to differentiate or classify landscapes. These levels of ecological organization are species, communities and ecosystems.

Landscapes are not only distinguished by biotic properties. The interactions between living organisms and the physico-chemical framework are crucial qualities of the systems. Until now, this **geoecological perspective** has not sufficiently been incorporated into the concept of levels of organization, which seems to be bio-centric.

2.3.2 Concrete and abstract landscape elements

Concrete elements and the abstract unit or type, to which they belong have to be distinguished (Zonneveld 1974). The real conditions are differentiated due to criteria as relief form, species composition, vegetation structure, or disturbance regime. The **classification of elements** compares the actual objects with given types of a general system (Table 2.3-1). The quality of classification may differ to some degree among the elements recorded in nature. Some are quite close to a specific class or type and it is easy to assign them to a certain label, others are more or less intermediate between two or three types. The application of different criteria might result in varying classifications of objects and in non-identical boundaries in the maps. It depends on the choice of criteria, where boundaries emerge.

What is true for concrete landscape elements can also be found for abstract **landscape units** (see Chapter 2.2). They also loose distinction with increasing complexity. At higher levels of organization it becomes more and more difficult to assign a real object to a certain type. The individualistic character increases from communities (Gleason 1926) to ecosystems and landscapes.

Table 2.3-1: Concrete and abstract landscape elements

level of organization	concrete element	example	abstract element	example
	actually existing, real		type, class, term, label, name	
organism	individuum	plant	taxon	*Poa pratensis*
community	stand, biocoenosis	meadow	syntaxon	Nardetum
ecosystem	ecosystem	agriculturally cultivated slope	geosyntaxon	agroecosystem
landscape	landscape	Central Alps	landscape type	high mountain landscape

2.3.3 Heterogeneity and homogeneity

Landscape elements show internal homogeneity, which distinguishes them from adjacent elements. All natural elements exhibit a certain degree of heterogeneity, and a certain degree of dissimilarity between them. Homogeneity and heterogeneity are a major qualitative topic in landscape ecology.

The two aspects of homogeneity or heterogeneity within and similarity or dissimilarity between elements, represent important qualities of **ecological variability and diversity**. It reflects the degree of self-organization and functional interactions, and thereby the role of ecological fluxes. **Self-organization** is the product of functional interactions between ecological compartments. The more interactions occur, the higher the degree of organization will be. The variability within a landscape element is not only determined by the number of different objects of lower levels of organization, which contribute to the emergence of new qualities of such an element, but also by their similarity. Following Whittaker (1972), these two qualities of variability can be expressed as α-diversity (number of elements) and β-diversity (similarity of elements). Heterogeneity is very much determined by differences in qualitative properties of single objects.

The **structural arrangement and heterogeneity** of landscape elements strongly influences our perception of nature. Physiognomic differences in landform or vegetation are the most obvious properties of landscapes (Figure 2.3-1). Three-dimensional structures not only reflect ecological site conditions, they contribute themselves strongly to the performance of water and light regime and thus affect communities and ecosystem processes (Holt 1997).

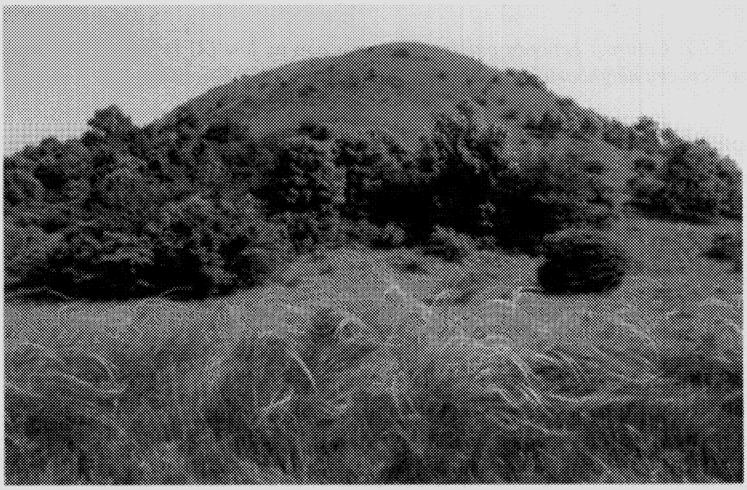


Figure 2.3-1: Structural heterogeneity within landscapes mainly addresses relief and vegetation: different vegetation types at the slopes of the hill Oblik (Bohemian Low Mountains, Czech Republic) (Photo: O. Bastian 1981)

Structural heterogeneity within landscapes mainly addresses relief and vegetation. Looking at **biotic structural heterogeneity**, different criteria for the description and analysis of spatial arrangements have been developed. At the level of organisms, life forms or growth forms became a successful tool for the description of spatio-temporal structures. Stands can be divided into different strata, which is conventionally done in forestry. At larger scale the physiognomy of vegetation can be classified to formations, dominated by certain life forms (e.g. forests) or showing a specific combination of life forms (e.g. savannah). Again, with increasing complexity **abiotic structures** as relief and interactions between plants and animals become more and more integrated.

The difference between an element and a neighboring element can be expressed as **contrast or β-diversity**. Contrast expresses the variability between two objects (Figure 2.3-2). Contrast is easy to measure with regard to some criteria, difficult with regard to others. The dissimilarity of species composition, nutrient supply, temperature, or inclination between patches can be calculated. Other criteria cannot or not completely be measured, such as ecological complexity, geomorphodynamics or climate.

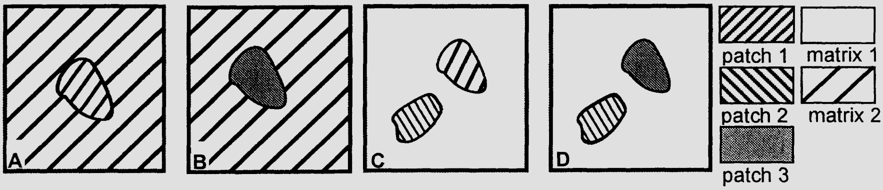


Figure 2.3-2: Contrast between patch and matrix can be low (A) or strong (B). But also the contrast between neighboring patches may be qualitatively different (C, D)

Contrast is scale dependent: with an increasing surface, the integration of elements and their individual variability grows. The same is true for patch internal heterogeneity expressing the texture of an element. Heterogeneity depends on scale (grain, resolution) and can be identified at different levels of resolution within one landscape (Kotilar and Wiens 1990).

We cannot discuss causes of heterogeneity and homogeneity here, but we have to point at the fact, that besides natural site conditions, human impact plays a major role.

Temporal heterogeneity cannot be separated from spatial heterogeneity. The seasonal variability of climatic factors, water regime, species occurrence and performance is a decisive quality of landscapes. If annual variability is low, the seasons and their effects on landscape elements are rather constant, which is true for tropical rainforests. Besides the occurrence of objects (e.g. species) and elements (e.g. communities) the time scale strongly determines the processes working within an ecosystem or landscape. If the ecological variability is concentrated on diurnal fluctuations and rhythms, this will influence the ecological relevance of certain processes, because species will adapt to this variability.

At longer time scales, ecosystem and community dynamics (including stability, see Chapter 5.1) can be observed. Ecosystems and most communities, though fluctuating during the year to a certain extend, show dynamic temporal changes within periods of several years or decades. Processes acting at this per-annual scale are population dynamics, growth, reproduction, soil erosion, land use changes. Looking at centuries and even longer times, long-term development of landscapes then includes evolution, geomorphological dynamics, soil development and phylogenetic evolution (see Chapter 4.1).

2.3.4 Patch, matrix and mosaic

Patches are concrete spatially delimited two-dimensional landscape elements at any hierarchical level and scale (Forman and Godron 1981). They can be differentiated from surrounding elements, which form a more or less uniform **matrix**. The contrast between patch and matrix ranges between completely dissimilar (no comparable objects or data) to nearly identical (only one or a few parameters differ). In addition, contrast can be considered between neighboring patches, embedded in the same matrix.

This contributes to landscape diversity. The number and the dissimilarity between patches characterizes important aspects of diversity at higher levels of organization. However, we have to relate this to the matrices respectively. If patch types are always closely related to a certain matrix with the same contrast, the resulting landscape will be less diverse compared to a landscape, where different patch types may occur in one matrix (Figure 2.3-3).

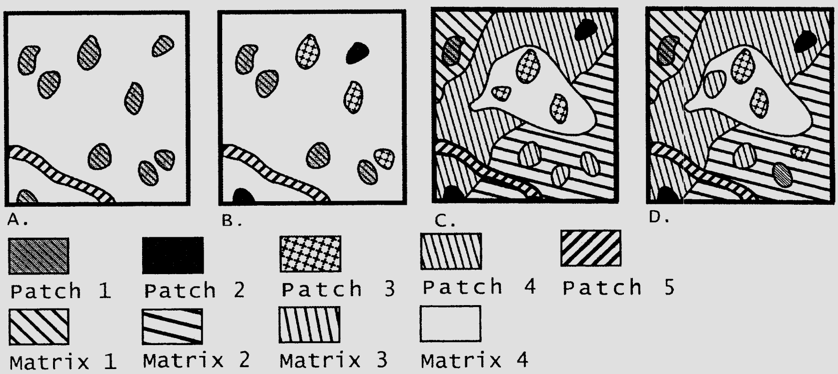


Figure 2.3-3: Heterogeneity relates to the number of patches, the patch/patch-similarity as well as to patch/matrix similarity. In a given number of patches occurs, which is qualitatively more diverse in B. In C and D the same number and the same types of patches occur, but they differ in their distribution to matrices. The same number and types of patches and matrices can produce a different landscape diversity

Landscape elements of a particular type may be rare or represented by numerous individual patches within a landscape. The same number of patches can be distant to each other or close. Distance is not correlated to the number of elements. Still, the relation between distance and number is modified by the size of the patches. And, apart from that, the distribution of patches follows ecological rules and is thus not stochastic. The size and the shape of patches within a landscape can be more or less uniform or different. This affects landscape heterogeneity.

Today, the patch-matrix model developed esp. by American ecologists is one of the most usual landscape models, besides the theory of geocomplexes elaborated mainly by Central and Eastern European physical geographers (see Chapters 1.1, 2.2 and 2.4).

In landscapes, patches, corridors and barriers are not mixed by hazard but arranged in a characteristic way. They form **mosaics of landscape elements** (Forman 1995, Wiens 1995), which develop under similar conditions in a comparable way. Natural examples are peat bogs, where different communities and vegetation structures form regularly similar vegetation complexes. In anthropogenic landscapes, land use will be determined by site conditions and result in comparable forms of land use techniques at comparable sites. This creates a mosaic of communities that will be found in a more or less similar composition at different places within landscapes. **Sigma-sociology**, derived from plant sociology, tries to identify these mosaics and to classify the corresponding vegetation complexes (Tüxen 1977). This sophisticated approach was aiming to be applied in nature conservation (Schwabe-Braun 1980), but could not become generally accepted, because it requires a high degree of experience and is biased when carried out by less trained field researchers.

If one focuses on the temporal development of mosaics, rules of change become obvious. In many ecosystems, we find a side by side of different stages of succession. A combination between spatial mosaics and dynamic changes in ecosystems is the **mosaic-cycle concept** propagated by Remmert (1991). It proposes a spatial and temporal relation between different phases of succession. Van der Maarel and Sykes (1993) developed a comparable model for vegetation units (the carousel model).

A more general model of change has been introduced with the **concept of patch-dynamics** (Jax 1994, White and Pickett 1985). Here, a close connection between the emergence of a patch and its history or neighborhood is not required. In contrast to the mosaic-cycle, within this patch dynamics concept, multi-disturbance occurrences at each stage of succession are considered.

2.3.5 Pattern and scale

Patterns are non-random spatial arrangements of objects within time or space (Collins and Brenning 1996). This means, that there must be a reason for this arrangement. It explains why the search for patterns is the major approach in landscape ecology (Turner 1989, Urban et al. 1987) and perhaps in ecology in general (May 1986).

Patterns emerge due to functional interactions between objects or elements. Patterns in European landscapes are mainly reflecting human activities (Burel 1995). As objects interact specifically, characteristic spatial arrangements of objects are probable. However, patterns are not only related to space. We find patterns in time series (e.g. Dunn et al. 1991), where, for instance, seasonal fluctuations follow regular patterns with correlation between data from neighboring patches. Pattern emergence cannot be separated from the problem of auto-correlation. Objects that contribute to the organization of a pattern will always be auto-correlated. As already mentioned, the detection of dissimilarities, and thereby of patterns as well, depends on criteria and scale (Turner et al. 1991). The identification of this scale is a task, which is difficult to meet. It is perhaps even more challenging to quantify landscape patterns (Gustafson 1998, O'Neill et al. 1988).

2.3.6 Connectivity, corridors, and fragmentation

Connectivity describes the degree of connection between similar landscape elements. It can be quantified via the number of corridors or vectors that can be related to an element (Tischendorf and Fahrig 2000). Connectivity between landscape elements may be strong or weak, spatial and/or merely functional (Figure 2.3-4). Strong spatial connectivity is produced by networks of corridors. Weak connectivity would be found within a landscape with only few linear elements bridging isolated patches. The necessity of spatial structures for the functional connection between isolated patches depends on the matrix and on the available vectors. Some vectors (e.g. birds, bees) are able to reach isolated patches without spatial corridors that connect them.

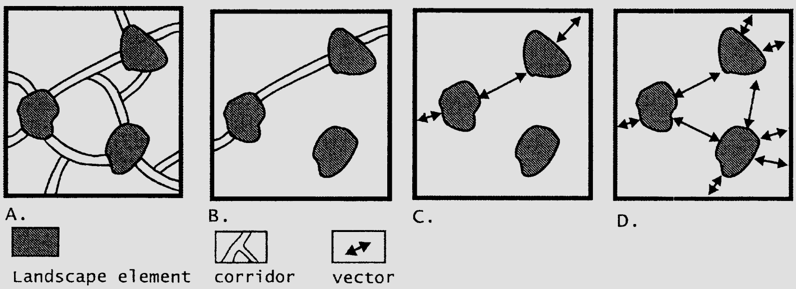


Figure 2.3-4: Spatial connectivity and functional connection A. strong spatial connectivity B. weak spatial connectivity C. strong functional connectivity D. weak functional connectivity

Spatial and (only) functional connections can be distinguished by the application of the terms "connectedness" and "connectivity" (in a narrow sense, see Chapter 2.8.4).

Corridors are spatial connections between landscape elements which are of functional importance for the interchange of species and for the flux of matter, energy and information. These functions can be bi-directional (Figure 2.3-5A). If the corridor connects two elements, fluxes and interbreeding can be effective in both directions. If we consider a network of patches and corridors, the interactions will be multidirectional. In these systems, movement and transport can be affected in any direction.

Some corridors, however, only work in one direction from source to sink (Figure 2.3-5B). This can be observed for river ecosystems and the drift of matter and diaspores they carry.

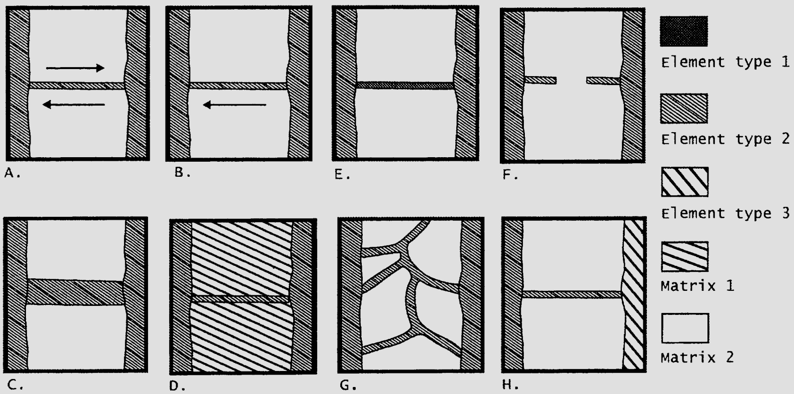


Figure 2.3-5: Different types of corridors: A. bidirectional corridor, B. unidirectional corridor, C. broad corridor with high capacity, D. corridor surrounded by similar matrix, E. Corridor with similar but not the identical conditions as source and sink, F. corridor not closed, G. corridor network H. leading to an similar but not identical sink

Corridors may be broad and cover large areas (Figure 2.3-5C) or small and of almost no spatial importance. To assure a desired function, a minimum corridor width is required, for instance for wildlife corridors that bridge motorways (Figure 2.3-6). Another quantitative aspect is the distance or length of corridors.

Corridors and their functional capabilities are strongly depending on the matrix they have to pass. If this matrix consists of landscape elements of very different environmental conditions compared to the connection, edge effects reducing their function will be stronger than if the matrix is rather similar to the corridor (Figure 2.3-5D).

Closed and entirely connected corridors (Figure 2.3-5E) are rare. Quite often corridors are dissected and comprise gaps (Figure 2.3-5F) resulting in functional restrictions. To improve the possibility for a specimen to successfully reach another patch, the number of connections between source and sink is of importance (Figure 2.3-5G). Finally, the functionality of corridors depends on the habitat quality of source and sink, which are connected. Similar patches are rare, so that exchange can be restricted by the capacity or attraction of the sink area (Figure 2.3-5H). The role of corridors for the mobility of organisms will be discussed in more detail in Chapter 2.8.4.

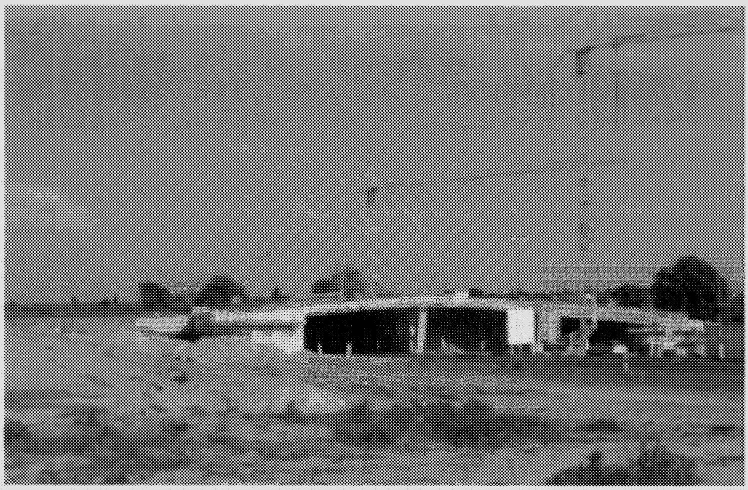


Figure 2.3-6: To reduce detrimental effects of fragmentation by motorways green bridges for the wildlife are built, e.g. near Dresden (Saxony, Germany) (Photo: O. Bastian 1999)

Fragmentation describes either a process or a status. Understood as a process, fragmentation depends on time and has to be related to landscape change. Then, fragmentation would describe the velocity of changes in connectivity. Fragmentation can also mean the separation of landscape elements that have been connected before. It can occur at different scales (Bowers and Dooley 1999).

Related to a surrounding matrix, fragmentation may describe the degree of isolation from other comparable patches. Related to corridors, it describes the degree of connection and the integration into a network. Here, the occurrence of linear barriers, which may be corridors for objects (species) bound to other elements or patches, has to be taken into account as well. Related to neighboring patches, fragmentation may describe the relatedness between the patch in focus with its neighbors and the distance to the next patch with favorable traits. Fragmentation influences the mobility of organisms, and thus, their survival, essentially (see Chapter 2.8.2).

2.4 Landscape ecological paradigms: correlation – hierarchy – polarity

2.4.1 Introduction

As shown in Chapters 1.2 and 1.4 landscape ecology as a science developed out of different roots (e.g. physical geography, biology, soil science) and focuses on a great variety of aspects. To meet the demand of transdisciplinarity landscape ecology has to contribute with its own paradigms, principles and laws governing landscape behavior.

Landscape as the object of landscape ecology can be considered as a subset of the earth's surface reaching through different "floors" (from the lithosphere as basement up to the atmosphere as the roof terrace). The penetration of lithosphere, atmosphere, hydrosphere and biosphere is – at least in geographical landscape research – called **landscape sphere** (see Chapter 2.1). In contrast to other geo- and bio-scientific disciplines physical geography is interested in the construction of the landscape sphere: each single unit can be characterized by a typical combination of natural features linked to other units by neighborhood coherence. Hence geographical landscape research is focussed on conformities of spatial differentiation, from the global and continental level down to the micro-units of only a few square meters and vice versa. All spatial units are delimited by a characteristic combination of many single features and they have characteristic relations to their neighboring units.

These conformities have been formulated first by Herz (1974) who named it the "**area-structure-principles**" (Arealstrukturprinzipien). The knowledge of these principles is indispensable to landscape ecological research. They represent general structural matter of facts. Following these facts processes of integration and differentiation peculiar to the landscape sphere carry out. The single principles have to be considered as parts of a whole.

Landscape analysis as the first step in landscape ecological research (followed by landscape assessment and landscape planning) investigates the landscape structure. Structural analysis provides the basis for a landscape classification as demonstrated by Bailey (1996) who did not mention one of these principles at all.

With respect to Figure 1.1-3 a landscape can be defined as a part of the earth's surface signed by the natural configuration and superimposed by human intervention. Hence landscape as a system consists of the elements geology, climate, soil, relief, bios, water as well as land use, represented in the specific spheres of the earth (lithosphere, atmosphere and so on). This general model serves as an aid for representation and as discovery help for the investigation of a specific landscape. Therefore it has an analytical as well as a didactic value. Based on this landscape model the four related area-structure-principles will be discussed in the following sections.

2.4.2 Principle of correlation

Starting with an inventory of the components of a parcel of land an inventory of its anatomy is provided. But it is not enough to dissect the land parcel, to cut it into pieces. Due to the fact that the whole is more than the sum of its pieces, we have to provide an understanding of how there parts fit together and how they function.

So the principle of correlation means, that there are specific interactions between all landscape components. How components are integrated at a site (or relatively small area), is called the **vertical structure** of a landscape (or **component structure**). Here, the interactions of macro-/topoclimate, biota, landform, surface water, soils, groundwater and bedrock are investigated (Figure 2.4-1, see Chapters 2.1 and 3.2).

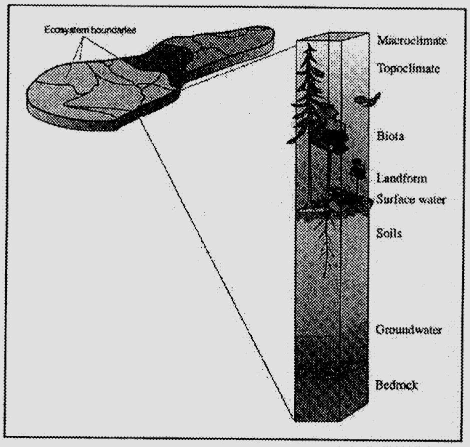


Figure 2.4-1: Vertical structure of a landscape (after Bailey 1996)

We will consider an example of the Sahara first: This site is characterized by dry-stabile stacked tropical air with great daily temperature amplitudes and low precipitation probability (macroclimate), by a water shortage throughout the year in soil as well as in autochtone water bodies (surface water), by extreme low species density and richness in fauna and flora (biota). Due to the air-masses the relief is shaped: on the one hand most of the mountains, hills, and ridges ("peak forms") are disintegrated to skeletons and all hollows, depressions and swales ("sink forms") are filled in on the other (landform).

Considering a landscape on a completely different level we can show, that structural correlation exists not only in large areas: A dune ridge in a pleistocene glacial valley is characterized by ridges of small hills (landform), dune sands poor in silt and clay (bedrock), sandy podzols (soil), deep aquifers (ground water), poor pine forest stands associated with ecological equivalent biocoenosis (biota). Also the climate of the near surface air layer and the soil differs from the neighboring sites: There is no danger of late frost, but some aspect related effects (topoclimate).

2.4.3 Principle of areality

As we know, the conditions of the landscape sphere varies from point to point – even in small scales: When we dig a hole for the investigation of a soil profile the four walls of our hole can be more or less completely different at least concerning the size of the single soil horizons or substrate layers. However, at the end we will consider this soil profile as a typical profile for this site. What we do is to abstract from singularities. We define the profile as homogeneous.

The same procedure has to be applied to the above mentioned vertical landscape structures. All the different existing feature correlations are limited to a specific area; they have a **boundary**. Boundaries between landscape units are set where different vertical structures occur (Figure 2.4-2). One specific vertical structure is neighboring another vertical structure. By delineating each specific vertical structure we come to the landscape's **lateral or area structure**.

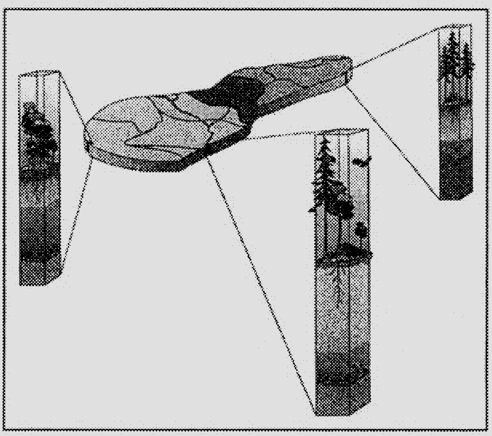


Figure 2.4-2: Horizontal structure of a landscape: Boundaries between single landscapes are set where different vertical structure occur (after Bailey 1996)

In landscape reality there are seldom sharp boundaries between single landscapes. Sometimes e.g. geology-based boundaries (different rocks) can be very sharp, but on other places we can observe smoothed transition zones between different landscapes. This is often the fact: One landscape turns into the neighbored landscape more or less gradually. As an example, the constantly moist European climates turn gradually into the summer dry climates of the Mediterranean and further into the constantly dry climates of the Sahara.

In the flat-waved plateaus of the European Massif Mountains we find the gradual turn from the more or less stony and dry soils on the hill-tops to the less-stony fresh to moist soils on the flat slopes down to the mainly stoneless and more or less wet soils at the flat-hollows.

From this the following question results: Do areas exist that can be named as homogeneous despite the general variation of the features? Is the landscape sphere composed by objectively separated units? Is the term of boundary only a useful abstraction?

A lot of scientist discussed these questions (Isacenko 1965, Maull 1950, Neef 1967, Schultze 1955) but their answers have not been unique and satisfying. According to Herz (1980) each area is characterized by a specific distribution of parameter values that differs from that of the neighboring areas. So an objective decision to determine landscape boundaries becomes possible. Additionally to the area-term the term of boundary-areas results: The boundary of a landscape is a narrow area of turn over from one specific distribution of parameter values to another. The values itself vary also across the border continuously but their specific distribution changes discontinuously. Due to the fact that boundary areas in reality – compared to the landscape areas itself – are only very narrow, they can be drawn as a line in a map (depending on the scale of the map and data available).

2.4.4 Principle of neighborhood (or principle of polarity)

One important advanced concession to the recognition of this principle of structure is the catena principle (see Chapter 2.6).

Each site constantly interacts with their surrounding sites through an exchange of matter and energy. If we approach landscape on a structural-functional basis, we must consider both the vertical structure (looking down vertically) of a site and its interaction with its surroundings: We have to consider the spatial association of vertical structure: the **process structure** (Figure 2.4-3).

Landscape processes are controlled by the landscape structure (i.e., how the components are integrated). Various structures and related process occur throughout any area. For making predictions about a landscape behavior information about the nature of its structure is required and how it varies geographically (spatially).

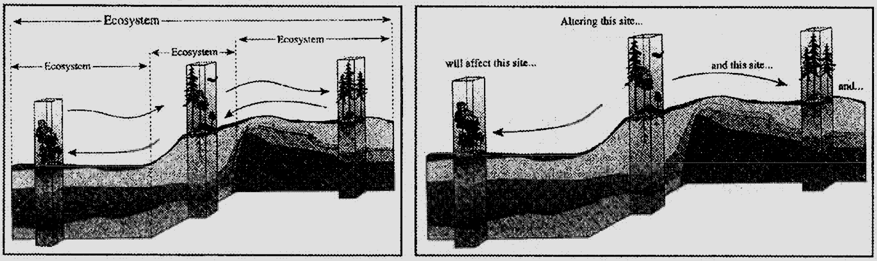


Figure 2.4-3 Landscape process structure: Interactions between landscapes

The principle of polarity rules the lateral diversity of the earth's surface. Their energetic wave-like value variation induces lateral fluxes of matter and energy along the earth's surface. Depending on different pattern/texture styles (arrangement of single landscape units, landscape mosaic) the fluxes of matter and energy are directed in a specific manner. Hence we can differ, for instance between similarity ranks and contrast pairs (Figure 2.4-4).

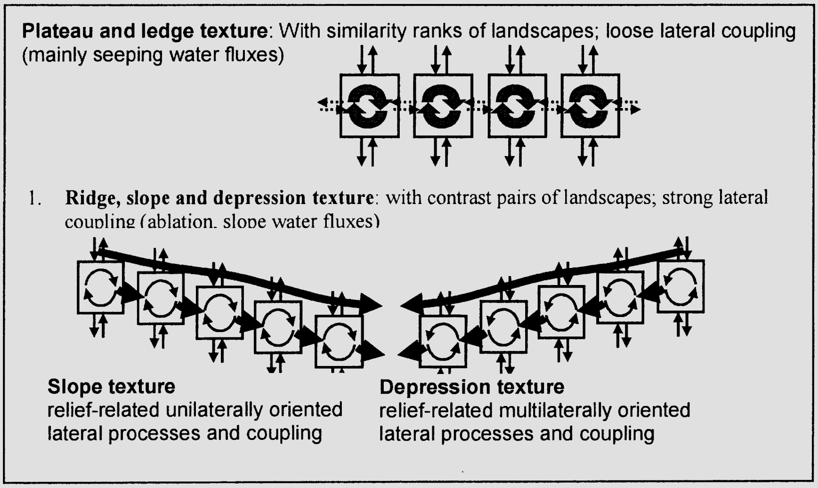


Figure 2.4-4: Different pattern/texture styles of landscape units and the movement of water and matter based on (after Billwitz 1997)

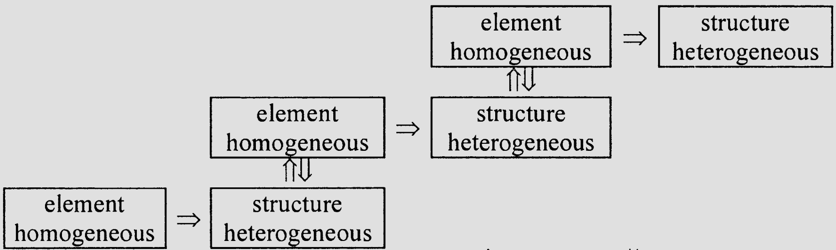
2.4.5 Principle of hierarchy

The principle of hierarchy is closely linked to the theory of dimensions in landscape ecology (see Chapter 2.2). According to this principle several landscape units of the same level can be grouped (ordered) to one landscape at the next higher level. In the opposite direction a landscape on a considered level can be subdivided into several landscape units of the next lower level.

Table 2.4-1: Scale levels of landscape ecological research, specific features and investigation methods (supplemented after Barsch 1988, 1996, Leser and Schaub 1995)

dimension	specific features	investigation methods
topological	single component features	analysis of geocomplexes (Neef 1963) topological site analysis (Barsch 1988) landscape ecological complex analysis (Leser 1991, Mosimann 1984b, see Chapter 3.4)
chorological	spatial combination of single features, biotope complexes soil societies	delineation of mosaic types (Neef 1963) chorological fabric analysis (Barsch 1988) chorological synthesis (Leser 1991)
regional	spatial distribution of leading features (tectonics, climate)	regional area analysis (Barsch 1988)
zonal geospherical	global distribution of leading features (climate, vegetation)	regional geographic formation (Leser 1991)

The hierarchy principle guarantees a regulated diversity. It is a matter of subordination, within at least three area dimensions are connected. Hierarchy is a structural principle, whereas pattern/ texture only represents the related conspicuous form.



association (⇒) and transformation (⇑ abstracting, ⇓ concreting)

Figure 2.4-5: Scheme for the investigation of the hierarchical landscape construction (after Herz 1994)

According to this principle a top-down as well as a bottom-up approach to landscape is possible. Landscape units of different levels can be distinguished by **classification of natural areas** – a top-down approach or by a **taxonomy of natural areas** – a bottom-up approach.

The natural regionalization as a method of classifying natural regional units starts at visible physiognomic units that will be subdivided into smaller ones. Thereby the criteria relief, mesoclimate, vegetation and soils are used.

It is directed more toward the formal structures of natural regions and less toward their functional structures. The most important methodological work in this field in Germany has been done by Paffen (1953). Based on this theoretical work a map of natural areas of Germany with written descriptions of the regions and a long methodological introduction has been created by Meynen and Schmithüsen between 1953 and 1962. Unfortunately this physiognomic approach was lacking essential ecological components including interactions between structures and processes. That is why at the end of the 60s the above mentioned method was supplemented by the taxonomy of natural areas that considers the methodological and practical necessity of quantitative description of regions. Nevertheless it had to deal with the difficulty to include functional ecological variables and processes adequately (see Chapter 6.1).

2.5 Landscape boundaries, ecotones

2.5.1 There is always something between something

Boundaries are everywhere. The human eye and mind differentiate and compartmentalize the world around us, the environment, into units: Rooms, chairs, trees, and mountains. If you have a discrete object, there has to be an end and a beginning to it, its boundary. The skin is the boundary for our bodies for example. It seems a two dimensional surface, but when we start changing scale, like use a microscope, the two dimensions dissolve into a space with three dimensions: hairs, pores, parts of skin etc. Two **fundamental concepts** of boundaries emerge:

- every boundary is in reality a boundary space, a three-dimensional body with boundaries of its own, and
- boundaries are scale- and observer-dependent.

For some microbes, our skin is the environment they live in, for us the skin is the transition to our environment. The necessity for formulating boundaries derives itself partly from the "hierarchy principle" (Blumenstein et al. 2000, see also Chapter 2.4). But those boundaries are analytical in nature and in reality divide a continuous universe. Nevertheless it is practical to delineate subsystems within our universe, simply because our imagination is not able to handle such complexity. The well-known parable of the watchmakers (Simon 1962 in Wu 1999) explains heuristically the need for using systems, subsystems and therefore the boundary concept: Two watchmakers, Hora and Tempus, were making equally fine watches, each consisting of 1,000 parts. Both were frequently interrupted by customers' phone calls, at which time they had to stop working, thus the unfinished watch at hand fell apart. Hora took the hierarchical approach by having his watch built with modules that were further composed by submodules, while Tempus assembled his watch directly from the parts. Eventually, Hora became a rich man, but Tempus went bankrupt. Simple probability calculations reveal that, suppose the probability of an interruption occurring while a part is being added to an assembly is 0.01. Hora makes 111 times as many complete assemblies per watch as Tempus.

If we use this boundary concept in landscape studies, we arrive at the concept of the **ecotone**. Ecotones divide units (homogeneous areas in the scale they are observed), they are often shown as a line on a map, e.g. the coastline on a globe. Clements (in Hansen et al. 1992) first mentioned the term "ecotone" in 1905. He observed that boundary zones between plant communities could combine characteristics of both adjacent communities as well as generate individual features of the transition zone. The roots of the term are Greek, "oikos" meaning household and "tonos" meaning tension. Until the emergence of the "patch dynamics theory", however, the term "ecotone" was unused. It became evident only recently, that ecotones in their function as transition zones actually define patches in the landscape.

A widely accepted **definition of** the term **ecotone** is as follows (Holland 1988): "Zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of the interactions between adjacent ecological systems."

Keeping in mind that an ecotone can vary in size and in ecological functioning it can be expressed in other terms as: "Ecotones can be viewed as zones where spatial or temporal rates of change in ecological structure or function are rapid relative to rates across the landscape as a whole" (Hansen et al. 1992).

Boundaries can be smooth or sharp, curvilinear or straight (Forman 1995). Straight boundaries and edges are mostly related to human activities and are likely to be anthropogenic. Modern agriculture and infrastructure tends to create straight and sharp linear boundaries. Curvilinear boundaries are more organic and often related to natural landscape elements, such as rivers. Most boundaries show spatial arrangements at different scales. They are organized in different fractal dimensions (Figure 2.5-1).

Van Leeuwen (1970) defined the **extremes of boundaries** as "limes convergens" (sharp edge) and "limes divergens" (smooth gradient). Although being addressed initially to plant communities, these terms were adapted to landscape elements of higher levels of organization. Perhaps due to the decline of Latin language in natural sciences, the terms ecocline (for "limes divergens") and ecotone (for "limes convergens") became more successful.

Initially, these terms were introduced by Westhoff (1974) to describe limits of plant communities.

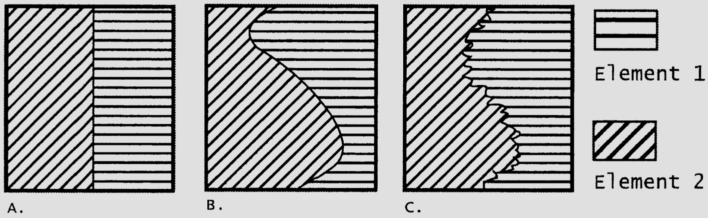


Figure 2.5-1: In landscapes different types of boundaries exist showing variability at different fractal dimensions. This is reflected in straight (A), curvilinear (B) or modified at multiple fractal dimensions (C) (draft: C. Beierkuhnlein)

Van der Maarel (1976, 1990) suggested that a gradual transition should be called "**ecocline**", while the term "ecotone" should be reserved for a sharp transition, an all-or-nothing scenario (see Chapter 2.3.2). So far, some studies have tested this theoretical concept (e.g. Backeus 1993), but the general definition of ecotone as mentioned above in conjunction with the scale dependency seem to have lead to the usage of ecotone for both scenarios. To clarify the concept of ecotones in relation to other concepts in ecology, Hansen and Di Castri (1992) differentiated the several terms (Table 2.5-1).

Table 2.5-1: Terminology for change in space and time

change in space	gradual	ecocline
	abrupt	ecotone
change in time	progressive	ecological succession
	sudden, nonlinear, chaotic	ecotone

2.5.2 Ecotones in theory

Figure 2.5-2 shows four ecosystems and their journey through time and space. Each ecosystem can be perceived as a ball rolling along its trajectory towards an unknown attractor. It has its particular place on the earth's surface (or ocean depth for that matter). Each ecosystem is controlled by different factors, their interactions as well as their changes through time. These are called "controlling factors" (Haken and Wunderlin 1991). In Figure 2.5-2, the array of controlling factors is symbolized by jacks, lifting the space/time continuum, providing possible trajectories and ultimately "channeling" each ecosystem on its way through time and space.

Ecosystem I is running up on a threshold in time, the controlling factors no longer support this particular ecosystem on that particular spot in space.

We could imagine a warming climate in northern latitudes leading to an invasion of tundra by trees. The ecosystem I, arctic tundra, is slowly replaced by another type of ecosystem, let's say boreal forest, ecosystem II. The arctic tundra, before a stable ecosystem on our space-time surface and therefore symbolized as a ball, is entering a **temporal ecotone** stage. The controlling factors no longer allow the existence of pure arctic tundra on this spot. In terms of general systems theory, the arctic tundra is moving through the stage of "critical slowing down" towards instability. This instability is symbolized by the ridge, the "threshold in time". From there, chance and the new controlling parameters will determine which new system will establish itself and where it is moving. This newly established system is truly unique and unparalleled. It might to a wide degree be nearly similar to ecosystems we can encounter in other places on the earth. But with a look on the time-space continuum, we can see that this point/ecosystem in time has its special and unique history. To what degree the history of this point will impact the future can only be guessed.

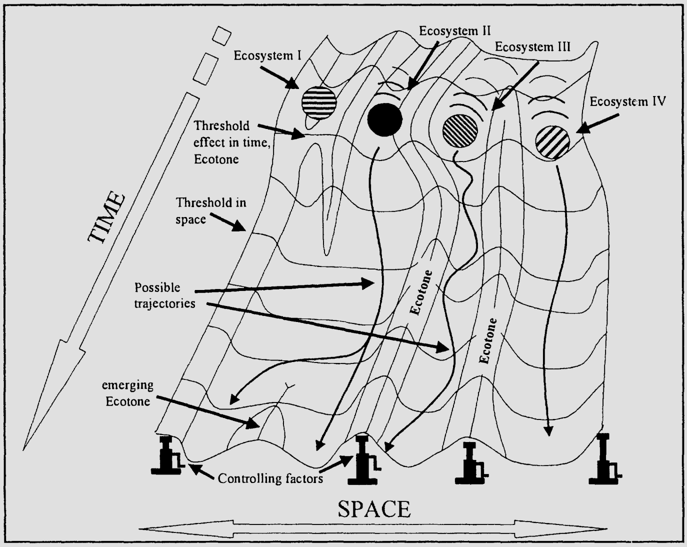


Figure 2.5-2: Four ecosystems on their journey through time and space. They are following their trajectories, guided by an energetic "landscape". Controlling factors are symbolized by jacks, lifting the time-space continuum, creating the conditions in which ecosystems and their ecotones evolve, exist and perish

Let us now focus our attention on ecosystem II. It is confined by an array of controlling parameters or environmental factors. They are symbolized by the ridges between ecosystem II and ecosystems I and III. These ridges are transition zones between two adjacent ecosystems, ecotones. They are themselves unstable and need input (energy, matter, information) from both sides/ecosystems to exist. As we can see, time changes the position of the **ecotone in space**. To stick with our image from the beginning, we could imagine shifting biomes due to climate change. The ecotones or transition zones between them shift accordingly.

As ecosystem II moves along its trajectory, it encounters a rising ridge, an emerging control parameter. As example we could think of the control parameter "human land use". Ecosystem II can no longer exist where additional energy input through intensive agriculture changes the environmental variables. The new and emerging ecotone might be the transition zone between forest and fields.

Ecosystems III and IV are moving along their trajectories, uninterrupted by unexpected, chaotic events or strange attractors. Ecosystem III might be recovering from a disturbance, staggering along. The curvy trajectory symbolizes resilience. The system is pushed and reacts with sideways motion, but does not go "over the edge". It remains stable in its setting.

2.5.3 Ecotones in reality

The recognition of a transition zone between two ecological systems by Clements (1905, in Hansen et al. 1992) could be called the beginning of ecotone research. Obviously the recognition focussed on the spatial aspect of ecological systems and their boundaries within a given area. Later on, after development of the theoretical foundations (which is still ongoing), the concept was used not only in spatial but also temporal terms (e.g. Delcourt and Delcourt 1992). Keeping in mind that every boundary and its classification is scale dependent, we can identify ecotones where

- a steep environmental gradient exists, that directly affects ecosystem function, structure and composition. Example: Boundary between forest and fields in anthropogenic landscapes, and
- nonlinear response to a gradual change of environmental variables is found, the "threshold effect" or the effect of cumulative impact. For example a pH change below 5.5 in the soil leads to mobility of Al^{3+} -ions with toxic effects on many plants as well as to ground water contamination (Blume 1990).

Ecotones as the boundaries between different ecological systems can emerge on a variety of **scales**. Just as the ecosystem itself can vary in spatial extent as well as occupy different levels in the spatial hierarchy (see Chapter 2.4), its boundaries, the ecotones can be found on different hierarchical levels. Gosz (1993) proposed an "ecotone hierarchy" ranging from the biome ecotone (the biome transition area) to the plant ecotone (Table 2.5-2). Examples of studies covering the whole range of scales in ecotone research are

Bretschko (1995), Kieft et al. (1998), Neilson (1993). The hierarchy is closely linked to probable constraints or controlling factors, which at the biome level are macroclimate and its variation through major topographic structure (Figure 2.5-3). The finer the scale and therefore the hierarchical level of the ecotone, the more controlling factors influence the ecotone. In addition to the number of controlling factors, their kind and type change with each hierarchical level. At the lower end of the hierarchy, the **plant ecotone** level, macroclimate and the major topography are constant, but the differentiation between different ecotones is rather controlled by factors such as microclimate, soil fauna, soil hydrologic regime etc. At increased finer scales the possible combination of controlling factors is much higher than at the coarser levels, simply because it is influenced by all factors above it in the hierarchy! The **biome ecotone** (a large scale phenomenon) may be a result of two or three controlling factors (in our perspective). The **landscape ecotone**, however, is already influenced by the biome it is located in, therefore by its controlling factors, PLUS additional factors on the landscape level. Macroclimate and topography are influencing the landscape ecotone as well as e.g. soil distribution, geomorphic structure and mesoclimate.

Table 2.5-2: Ecotone hierarchy, based on Gosz (1993)

	ecotone hierarchy focussed on ecology	proposed hierarchy focussed on integral ecological landscape units	controlling factors (each ecotone is influenced by controlling factors of its own level and in addition by every controlling factor above its level)
macro scale		land-ocean ecotone (global)	distribution of continents on earth surface
	biome ecotone	ecozonal ecotones	macroclimate, major topography
mesos cale	landscape ecotone	landscape ecotone	mesoclimate, geomorphic processes, soil characteristics
	patch ecotone	top ecotones	microclimate, microtopography, soil/soil moisture variation, species interactions
micros cale	population ecotone,		interspecies interactions, intraspecies interactions, physiological
	plant pattern		controls, population genetics
	plant ecotone		soil fauna, soil flora, soil chemistry

The highly differentiated site conditions of ecotones cause special combinations of species and communities, a high richness in species is usual (see Chapter 2.8.5), but ecotones can also display less biodiversity than the neighboring ecosystems (Neilson et al. 1992). But ecotones often act as **barriers** in ecosystems (Blumenstein et al. 2000). They are always areas of discontinuity. This discontinuity explains in part the emergence of structure as part of feedback loops. Once a boundary is manifested, gradients will control the flow of energy, matter and information across it. The different strength of gradients leads to increased differences in the two systems bounding the gradient. In the soil for example, differences in the redox potential of a water saturated sediment layer can lead to different felling of Fe- and Mn-molecules. This is an important prerequisite for the development of rosty patches and concretions in the oxidized layer of a gleyic soil (Scheffer and Schachtschabel 1992).

Figure 2.5-3: The forest steppe zone in Asia is a broad ecotone between the steppes in the south and the zone of compact forests (taiga) in the north. Due to extreme climatic conditions, and supported by human activities (timber cutting, grazing), in the northern Mongolian mountains mainly northern slopes are covered by forests, while dry southern slopes are dominated by grass and herb steppe ecosystems (Photo: O. Bastian 1994)

The ecotone concept can be applied to both spatial and temporal investigations. If we could directly observe one particular spot on the earth's surface through time, we would always see change under way and never perceive a stable state of this one spot for very long. Through thousands or even millions of years our spot might change from being part of the ocean to a shallow lake to a steppe type ecosystem. We would maybe see a cooling of temperatures, a change in species composition, the advancement of the ice shields, their retreat and the recolonization of our spot starting with gravelly soils, the first lichens arriving, mosses, brushes etc. until we might see a forest. Through some of our observation we could identify an ecosystem in a quasi stable state, meaning that the controlling factors and their "answer by nature", the ecosystem at that time, are in equilibrium. A lot of scientific research has focussed on these "stable states" and only lately has attention been given to the dynamic and change of these systems. These times of increased change, maybe even catastrophic in nature, are ecotones in time.

2.5.4 Delineation of ecotones

Methods for ecotone detection include spatial analysis (GIS and remote sensing, see Chapters 6.2 and 6.3) for the detection of patterns in space (Fortin et al. 2000) and statistical methods applicable to both spatial and temporal datasets. Fortin et al. (2000) also include modeling as detection methods for ecotones by formulating and predicting interactions in multivariate datasets. In general, ecotone detection is the ability to determine spatial or temporal change (Johnson et al. 1992).

Table 2.5-3: Overview of statistical methods available for detection, measurement and characterization of ecotones (from Fortin et al. 2000)

ecotone attribute	data type grid data (raster format, e.g. in GIS)	transect data	sparse data, unevenly distributed
detection	edge detection algorithms and kernels	magnitude of first difference	irregular edge detection
location	thresholding of edge operations	maximum of first difference	functional criteria
width	goodness of fit for location statistics	magnitude of first difference	magnitude of first difference
evenness	dispersion of width along boundary		dispersion of width along boundary
sinuosity or Curvilinearity	length of boundary as a function of grid precision; fractal dimension		length of boundary as a function of grid precision; fractal dimension
coherence and significance	boundary statistics overlap statistics (different between boundaries in vegetation, soil, etc.)	coincidence of limits more often than by random chance	boundary statistics overlap statistics (different between boundaries in vegetation, soil, etc.)

For an overview of statistical methods concerning detection of patches in landscapes and therefore ecotones as their boundaries see Fortin et al. (2000), Johnston et al. (1992) and Turner et al. (1991). Some detection mechanisms include: GIS functions (e.g. pattern recognition, optimal corridor location, fractal dimension), "moving (split) window" technique, especially suited for transect data, "wombling" (lattice, triangulation, categorical), essentially a two dimensional form of the moving split-window technique. Once ecotones are detected they can be measured for width, verticality, evenness and curvilinearity (total length divided by straight line length) or sinuosity (length of ecotone per unit area using fractal dimension, Table 2.5-3).

2.5.5 Ecotones and change

Ecotones are often described as "early warning stations" for a change in structure and composition of the adjacent ecosystems (Allen and Breashears 1998). Meaning that if controlling factors are changing (e.g. mean annual temperature increases under global warming scenarios), the change and effects of that change can first be detected in the boundary zone, the ecotone. This is based on the assumption that the limiting factor delineating the spatial extend of that ecosystem at that time continues to be the limiting factor after the change took place. This is not always the case and studies not supporting this view are documented (Neilson 1993).

Let us look at one example, the **treeline-ecotone in interior Alaska:** During the last decades, the Arctic and Subarctic are experiencing warmer temperatures both in summer and winter (Juday et al. 1998) and global change is heavily impacting high latitude ecosystems. One of the most visible natural ecotones is the treeline-ecotone, dividing in our case the boreal forests and the arctic or alpine tundra. Fundamental interest in the question of possible treeline movement under global change is fueled by the question of carbon uptake of the boreal forest ("sink-source question"), albedo changes and other feedback loops between boreal forest and global climate (Foley et al. 1994). This treeline is generally thought to be correlated with the July 10°C isotherm (Daubenmire 1954). The limiting factor for tree growth is therefore believed to be temperature. Under global change scenarios, the vegetation zones will eventually adapt to higher mean annual temperatures and changes summer and winter conditions (Chapin et al. 1995). This logical reasoning is based on the assumption that temperature will still be the limiting factor for tree growth under changed conditions. However, new findings suggest, that the limiting factor for tree growth and establishment may have shifted to moisture supply within the boreal forest and at least parts of the forest-tundra ecotone in Alaska (Jacoby and D'Arrigo 1995). Briffa et al. (1998) reported a decreased sensitivity of radial growth of high latitude trees to temperature since the mid 20^{th} century. This would have a major impact on the forest-tundra distribution in interior Alaska. Two scenarios are most likely:

1. The forest will expand into tundra with increased summer air temperatures, providing a higher CO_2 uptake and a negative feedback to the greenhouse effect (our "limiting factor stays the same scenario")

2. Under increased summer air temperatures the limiting factor of tree growth will shift to moisture supply, possibly leading the ecosystem trajectory towards higher fire frequency, massive die-back of white spruce due to moisture stress and slow change into aspen parkland, resulting in another positive feedback loop with less CO_2 uptake and increased greenhouse effect.

These scenarios make clear that completely different outcomes are possible due to a small change in the ecosystem trajectory. There is no real way of sure prediction. Predictions based on linear causal chains might just be lucky hits, if nothing fundamentally changes within the ecosystems in question. As outlined above, this is not always (actually seldom, Briggs and Peat 1993) the case. Under these more realistic circumstances we will be able to use a ton of colorful prediction maps as wallpaper in storage rooms. Going back to Figure 2.5-2 we can now ask, if the boreal forest ecosystem faces the destiny of ecosystem I, running against a threshold in time and subjected to fundamental changes in internal structure, or ecosystem III, shaken, but still on its way through time, adapting by spatial change and shifts in biome location.

As a careful first **conclusion** we might say that:

- Small and slow shifts in controlling factors lead to a gradual spatial shift of the ecosystems involved as long as the limiting factor is not changing. The change can be first detected in the ecotone areas.
- Catastrophic events, nonlinear responses and change in limiting factor can lead to different ecosystem trajectories, change is not first detected in the ecotones.
- If the monitoring interest is focussed on ecotones in time, the core areas of biomes might provide a more suitable homogeneous background for detection of change, e.g. regional drought-stress (Neilson 1993).

2.6 The catena principle

Experience of surveying natural units in hilly areas has shown that certain ecotopes regularly recur within certain natural areas on the chore scale. Although working separately, both Haase (1964) and Klink (1964, 1966) introduced the term "ecological catena" for such regular sequences of ecotopes during their studies in the hills of Lusatia and in the highlands of Lower Saxony, respectively. The term is actually an extension of the catena concept coined by Milne (1935) and Vageler (1955) in mapping tropical soil series. Such ecological catenas were termed "Standortsketten" (**site chains,** Kopp 1961) in forestry mapping, and Standortsreihen ("site series", e.g. Schmithüsen 1968) in vegetation geography.

The **soil catena** comprises a natural sequence of soils, while the **ecological catena** consists of ecotopes spatially linked together. Its internal and external characteristics can be demonstrated quite clearly by means of profile sections through natural chores and maps of ecotope structure. As a rule certain basic trends of regional natural development can be identified, i.e. ecological catenas have a certain make-up in terms of landscape genesis.

However, the ecological catena is not just the result of a natural area's chronological development, but is also subject to current ecological processes, especially the water-based transfer of dissolved and solid substances. Such processes cause constant impoverishment to hilltops (and general denudation edges) and upper slopes where substance transport occurs, accompanied by faster desiccation compared to lower hillsides. Mainly substance transport takes place in middle hillsides (in connection with interflow and surface run-off), while the soil water flows towards the lower slopes, resulting in the accumulation of the substances thus transported.

The combined result is an improvement in lower hillsides and the area at the foot, assuming the root area is not restricted by water-logging. The lower hillsides are the most valuable areas for both forestry and agriculture. Assuming the slope is not too steep, crops can even be raised here in hilly areas.

In addition to current relief-controlled processes affecting the ecology and pedogenesis, weathering and soil formations from previous stages of geological development contribute to the formation of ecological catenas. Of particular importance in this respect are morpho-pedogenetic processes dating back to the Ice Age. In hilly and mountainous periglacial areas in Europe, North America and the rest of the world, underground rock often only reaches the surface at hilltops, hillside edges and upper hillsides, providing the source rock for the usually flat soils (see Figure 3.2-4). By contrast, the source rock of lower slopes comprises Quaternary and especially Tertiary weathering cover on crystalline rocks (debris, upper layers and surface layers) (AG Boden 1996, Fried 1984, Semmel 1964, 1966, Stahr 1979, Völkel 1992, Zepp 1999). Lower down, the thickness of these top layers generally increases, and clear stratigraphic division can be seen. Sometimes they consist of the weathering of crystalline rocks (granite, gneiss) from the Tertiary, whose transition to the source rock is diffuse but which is clearly separate from the Pleistocene cover originating elsewhere. Normally, however, these upper layers are the result of frost dynamics and comprise migrating debris from the Ice Age mixed with fines transported by water and wind. On lower slopes and at the foot they are often covered by younger eolian loess deposits. On the basis of the frequently recurring features, the German Soil Study Group differentiates between the following migrating layers:

- bottom layer: widespread, free of loess loam, compacted, containing consolidated rocks and similar substances to the underground rock,
- middle layer: mixed with eolian fines, frequently unconsolidated rocks, clearly separate from the base layer but diffuse transition to the main layer, and
- main layer: occurring almost everywhere outside Holocene erosion and accumulation areas, mixed with eolian fines; substrate for Holocene soil formation (AG Boden 1996).

The accumulation of periglacial weathering material and Holocene erosion products (humus, fines) increases the storage area for soil water throughout the lower hillside area and at the foot. In addition, the increase in fines raises the sorption capacity. The soil profiles increase in depth, causing the root area to expand. These are all ecologically favorable criteria for greater biotic productivity in such lower hillsides and bottom area.

On lower slopes, springs sometimes emerge above dense rock (such as in crystalline areas) from the water-saturated debris layer. The toposequence of floodplain forest sites on various old river terraces with varying groundwater levels, various sediment cover, and decreasing flooding frequency and duration at higher altitudes, can also be described as ecological catenas (Figure 2.6-1).

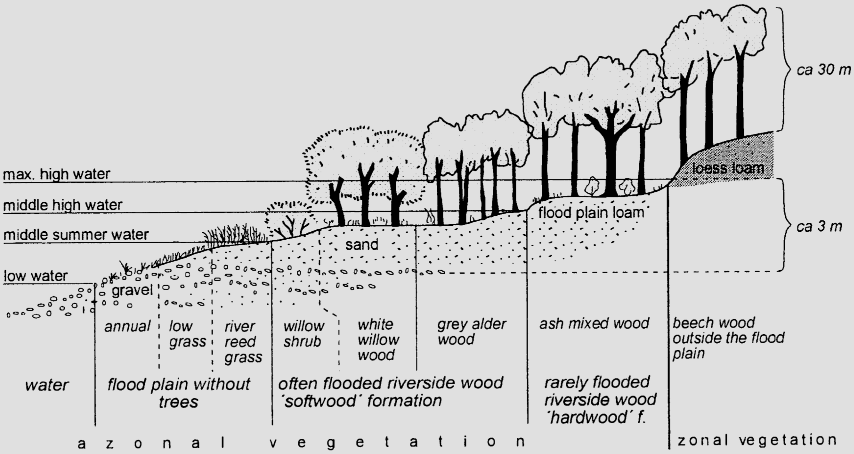


Figure 2.6-1: Typical ecological catena from the middle reaches of a river in the northern Alpine foothills (Alpenvorland) (hydro-topo-sequence)

Above all on broad slopes on taller mountains, the edaphically caused local division is also influenced by the terrain climate. For example, cold air regularly builds up in valleys, particularly in transition seasons, which affects the lower slopes. The thermal regime is more balanced in the middle slopes (the air is mixed as cold air flows away), while at higher altitudes the lower temperatures usually result in greater rainfall.

All in all, the ecological catena is an important principle of classification in the natural landscape structure. It brings together ecotopes connected by lateral substance flows to form a topographical ecological complex. Recurring catenas in a region are important criteria for the designation of natural areas on the scale of chores, especially microchores.

2.7 Water-bound material fluxes in landscapes

2.7.1 The importance of water-bound material fluxes in landscapes

The structure and distribution pattern of landscape elements such as land use, land cover, soils and relief determines **fluxes of water, material and energy** in landscapes. Flux interactions within and between different types of landscape are also important (Volk and Steinhardt 2001). Turner and Gardner (1991) point out that a consideration of horizontal nutrient transport across landscapes requires an understanding of spatial and functional biogeochemical diversity. Shaver et al. (1991) describe an approach to developing a spatially explicit nutrient budget for a heterogeneous landscape in the arctic. Their approach views heterogeneity from the process level and allows the importance of spatial pattern for nutrient transport to be estimated. However, the pattern or heterogeneity of processes may or may not correspond to the heterogeneity of the patches observed by a human (Turner and Gardner 1991).

The ecosystem concept, with its central terms **structure** (physical, chemical and biological) and **function** (materials and energy), is applicable at the landscape scale (Aurada 1999). The concept that ecosystems are substantial and energetically open systems, with material and energy flows influenced input-output-relationships is also relevant. Key external or internal processes influencing materials flow are erosion, surface water movement and nutrient leaching. The type of process and its flow rate are a function of climate and landscape structure and they can be initiated, affected or regulated by human activities. In extreme cases impacts can result in lasting disturbances such as landslides, flooding and damage to crops of wildlife habitats. The time scale at which each process operates is variable (Zepp 1999).

2.7.2 Disturbance of water-bound material fluxes by human impact

Land use is increasingly modifying material cycles and exchange processes in the biosphere (Häfner 1999) by **changing landscape structure.** It has a strong impact on the adaptability, the regeneration, regulation capability of ecosystems at the landscape scale (Volk and Steinhardt 2001). Activities such as the sealing of land surface and consolidation of farming have impacts on the duration, range and intensity of water-bound material fluxes within and between different types of landscapes. Additionally, the mode, concentration and composition of the transported material such as waste and sewage from settlement and industries, pesticides and fertilizers is changed by human activities and result in environmental, social and economic stress. Estimation of the spatio-temporal input behavior of selected pesticides (Grunewald et al. 1999) is needed to understand their impact.

Studies from different parts of the biosphere deal with the consequences of **site-unsuitable land use**. Consequences include the transport of nutrients like phosphorus by surface run-off, or the leaching of nitrogen to groundwater. Soil erosion can lead to lower crop yields in the damaged areas (on-site-damage). Off-site-damage caused for example by increased sediment and nutrient loads into water bodies.

The high **nitrate load** of the groundwater investigated at many extraction-wells for drinking water, especially in agricultural landscapes, can require the admixture of drinking water with low nitrate values. As a result, many drinking water suppliers and environmental institutions see a need for acting to reduce nitrate leaching into groundwater.

Since the beginning of the 20th century, consolidation of farming has led to a decrease in biotope diversity throughout Europe. Remaining biotopes are also affected by nutrient input, for example, from arable land. The effects are damaging to oligotrophic biotopes (Kleyer 1991).

2.7.3 Problem-solving approaches

We live at a time in which radical and far-reaching decisions on managing ecological conditions and the functional capability of biosphere-scale ecosystems need to be made (Häfner 1999). Such important decisions require comparable information about the spatial distribution, temporal cycles and process interactions within the global system.

Integrated approaches and **model simulations** dealing with the spatial and temporal description of the impacts of natural changes and particularly land use induced changes on water and material balance are required. A comprehensive description of methods for landscape ecological analysis applied in Germany is given by Bastian and Schreiber (1999) and Zepp and Müller (1999). The most developed investigation methods are for small scale studies, with recommendations for methodological standards in mapping, measuring and assessing mostly up to a scale of 1:25,000. There is no standard approach for investigating integrated landscape analysis on the meso-and macroscale (Lenz 1999). Most of the nutrient load of surface waters originates from non-point sources. For the analysis of these processes, the application of models in combination with geographical information systems (**GIS**) is a useful approach (see Chapter 6.2). Spatial variability of the landscape characteristics and their influence on the transport of water and nutrients within a given area is important. Chapter 6.4 refers to the relevant methods, models and approaches. The investigation of processes at different scales is essential for a better understanding of the transport mechanisms and spatial interactions for regulating water-bound fluxes have to be improved as a contribution to protecting natural resources such as water and soil, especially in cultural and agricultural landscapes (Figure 2.7-1).Land use regulation is a steering option for the sustainable management of water-bound material fluxes in landscapes (Neumeister 1987). In addition to abiotic components of the landscape, biological processes are also important in understanding water-bound fluxes (Finke 1994, Wohlrab et al. 1999).

One of the most important topics in landscape ecology is the differentiation between **vertical and horizontal fluxes and processes**. Most process-oriented investigations are focussed on small sites. These studies have contributed particularly to vertical processes at the microscale. On the mesoscale, horizontal processes are the main focus of consideration (Leser 1997). A problem arises in transferring information about horizontal processes to nature areas or watersheds recorded at one point in time - in spite of several studies dealing with theoretical aspects, the improvement of field analysis and "scale-transfering" techniques (Schmidt 1978, Volk and Steinhardt 2001).

Figure 2.7-1: Rivers are paths of matter fluxes within and across landscapes: Flood of the Elbe River in Dresden, capital of Saxony (Germany) (Photo: O. Bastian 1999)

Menz and Kempel-Eggenberger (1999) suggested combining landscape ecological methods and analyzing at two scales to partly resolve these problems. At the microscale, they followed the concept of the **landscape ecological complex analysis**, with time-dynamic measurements of water and material fluxes (Leser 1997, see Chapter 3.4). The main step of these investigations is **local analysis** of landscape complexes with the conceptual model "local-site regulation cycle" ("Standortregelkreis", Chorley and Kennedy 1971, Mosimann 1978). This theoretical model includes different spatio-temporal dimensions that can be used to scale up material fluxes and transformations. Because of the problems with the transfer of local process information to larger areas, Herz (1994) suggests the development of hypothetical key factors or connecting links between the different scales. The method used in this approach is **digital ecological risk analysis.** It is based on a classification of homogenous units of process attributes (Leser and Klink 1988).

The combination of structural and process parameters and the application of classification and assessment methods (e.g. Marks et al. 1992) enable the designation of ecological zones sensitive to specific natural and anthropogenic impacts. By modifying the classification and assessment methods, transfer to larger areas (regions) is possible. In addition to the problem, that there is less information about process dynamics and process behavior in these structurally oriented studies, most of the existing assessment methods are valid only for scale levels up to 1:25,000. Nevertheless, Menz and Kempel-Eggenberger (1999) suggest the combination of these two methods as a base for defining of connecting links between the dimensions (?) that allow a scale specific characterization of the process transformations.

The importance of changes in ecological and socio-economic parameters depends on the spatio-temporal level (Mosimann 1999, Steinhardt and Volk 2000). Thus, we suggest a **hierarchical approach** for investigating and assessing landscape balance.

With the **completion and combination of "classical" methods** such as measuring, mapping and assessment **with innovative GIS-model-applications**, the problem of the verification of meso- and large scale model calculations of the landscape balance should be solved. These approaches are important for the progress of scale related landscape ecological research, considering questions of system behavior, adaptation, feedback mechanisms, hierarchies, synergy, etc. A remaining problem is the definition of links between the different scales. Another question is the degree to which often such "philosophical", difficult and complex system approaches have to be simplified for applications e.g. to environmental planning. Here, a combination with more practical approaches, such as is suggested by Bierkens et al. (2000), is relevant.

2.7.4 Conclusion and outlook

In consideration of the "state-of the art" of investigating water-bound material fluxes as a field of landscape ecology, many open questions remain. Thus, future research should be addressed to the following topics (Volk and Steinhardt 2001):

- Improving the **understanding of landscape ecological processes**: interactions between landscape pattern and processes. This objective requires further development of models and scale-specific assessment methods. A promising development is the further progress and application of object- and cognition-based remote sensing methods.
- **Improving the availability of large area data bases,** the development of transfer functions and the upgrading of so-called "hydrological remote sensing" methods.
- Gaining knowledge about the **"natural" dynamics and adaptation of ecosystems** (present "ecological" assessments are mostly process oriented, especially on larger scales, particularly in relation to human impacts and land use.

The inclusion of information about water-bound material fluxes and other ecological processes is important for nature and landscape protection. Relevant questions asked by Mosimann (1999) are:

- How large should areas be for the near-natural of running water systems?
- How will the current spatial structure of agricultural landscapes influence future vegetation patterns if land use becomes less intensive?
- How can climate and water balance-related processes be used to predict the development of vegetation?

Today, sophisticated models exist that describe, analyze and predict ecological conditions and processes at small scales (see Chapter 6.4). At the mesoscale, however, this is not the case. Thus, landscape ecology should focus increasingly on these mesoscale investigations. However, the quality and availability of the input data relating to functions for a process-oriented modeling in commercial Geographical Information Systems (GIS) is poor. The availability of process data could be improved by coupling of GIS with external simulation models (see Chapter 6.4).

2.8 Dispersal of organisms - biogeographical aspects

2.8.1 Reasons and modes for organisms' mobility

The distribution of plants and animals in a landscape is dynamic. At the species and population level, mesoscale spatial changes take place, with the extension or reduction of the area of distribution. Weeds and insect pests invade, e.g., from surrounding biotopes. Dispersal mechanisms are driven by wind and water. Animal locomotion for foraging, mating, and hibernation on a daily or seasonal basis takes place within or between habitats. Dispersal is a process which can **change the geographic range** of species. Many animals need landscape heterogeneity to survive and complete their life cycle. **Seasonally available habitats** can contribute. They may be separated by considerable distances, ranging from less than a kilometer to thousands of kilometers. The seasonal migrations of animal species are well-known and spectacular: amphibians to ponds for spawning, herds of big African game for water and feed, migrating birds for hibernation even between continents. In agricultural landscapes, many animals follow hedgerows to move between habitats.

Most species have different **seasonal diets**. The capercaillie *(Tetrao urogallus)*, for example, eats pine needles in winter and herbs and berries in summer. The chicks are obligate insectivores in the first weeks after hatching, whereas the adults are herbivores. During daytime, bird rest at ground-level in dense vegetation to avoid detection by day-active raptors, whereas they roost in trees at night to avoid night-active mammalian predators searching for prey by smell. To stay alive and produce viable offspring during its lifetime, a grouse needs a wide variety of different habitats within its ecological neighborhood (Rolstad 1999). The red-backed shrike *(Lanius collurio)* needs a large variety of insects. The old-fashioned cultural landscape of mixed farming supplies an optimal variety of patches, each with a different kind of crop or treatment, which in turn guarantees the insects. Similarly, the stork *(Ciconia ciconia)* depends on this type of landscape to supply consisting of insects, small mammals, amphibians reptiles, etc. (Ringler and Heinzelmann 1986). The life zone of the common viper *(Vipera berus)* consists of the basking, hunting, mating and underground cover. Habitats are also needed during the summer and for over-wintering. Migration and dispersal routes between the habitat fragments are also required (Schrack 1999).

2.8.2 Fragmentation and isolation

The relationships between landscape structure and population dispersal depend on biological characteristics such as size of home range, dispersal mechanisms and the ability to cross distribution barriers (sensitivity to fragmentation).

The flux of organisms in landscapes is highly modified by human influences. There are many studies of plant and animal dispersal and distribution in relation to **landscape structure**, e.g. Burgess and Sharpe (1981), Farina (1998), Forman and Godron (1984), Jedicke (1994), Mader (1981), Usher and Erz (1994), Wiens (1999), various IALE congress proceedings such as Brandt and Agger (1984), Ružička (1988), Schreiber (1988), Turner (1987) and many papers which have since appeared in "Landscape Ecology", "Landschap", "Naturfredningsradet og Fredningsstyrelsen" and elsewhere.

Habitat **fragmentation** caused by land use processes such as woodland clearance, intensive agriculture, urbanization has had an enormous effect on habitat distribution and composition (see Chapter 2.3.7)

Clearance and fragmentation of natural areas have occurred, and continue to occur, in every continent throughout the world. It is one of the major issues confronting wildlife conservation on a global scale. Fragmentation is occurring on at an alarming rate, reducing large forest cover as well as natural prairies. It has different effects on habitat fragmentation results in:

- decrease in biotope size,
- increase in the ration of biotope edge to area (see Chapter 2.8.5),
- increase in distance between biotopes and population isolation, ecological distortion of the biotope environment by foreign materials, drainage and surface sealing (Jedicke 1994).

The consequences of fragmentation for flora and fauna have been interpreted and investigated by the general framework of the **island biogeography theory** (McArthur and Wilson 1967). This theory explains the observation that islands contain fewer species than mainland areas of comparable size. An island biota is characterized by a dynamic balance between the immigration of new species to the island and the extinction of species already present. Immigration rate decreases with increasing distance of the island from source areas, while extinction rate decreases with increasing island size. The two events, immigration and extinction, result in a constantly changing species composition (species turnover) on the island. Taking into account their low immigration and high extinction rates, small islands will be characterized by high species turnover rates. The chance of successful colonization of very isolated islands is reduced. The result is that the biota of more isolated islands will equilibrate at lower species richness levels than that of less isolated islands. In addition, the predicted decline in species numbers to a new dynamic equilibrium on newly created islands is dependent on the area of the island; the greater the area, the slower the rate of this decline.

The island biogeographic theory used to explain species richness on oceanic islands has also been applied to isolated habitat patches in terrestrial landscapes (Figure 2.8-1). Such **habitat islands** can be characterized by:

- high turnover by species through immigration and extinction,
- increase of species' numbers with increasing area,
- human-influenced edge zones,
- modified species spectrum in favor of ubiquists especially in the edge zones,
- impoverishment in species number,
- dominance of only a few animal species,
- increased chance for a genetic differentiation of isolated populations.

Figure 2.8-1: The island biogeographic theory is also applied to isolated terrestrial habitat patches, for example in the agricultural landscape: A small woodlot within arable fields near Moritzburg (Saxony, Germany) (Photo: O. Bastian 2000)

The island biogeography theory has met with criticism, since area size and isolation factors are not enough to explain fully the effects of fragmentation in habitat islands. Factors, such as habitat heterogeneity, connectivity, the presence of ecotones and corridors, and the metapopulation structure (see below) have also to be considered (Farina 1998).

Isolation can be advantageous in some circumstances, for example, evolution and its selection process require isolation. This applies to all natural systems at any scale (Zonneveld 1995). Corridors (see Chapter 2.8.4) can increase the exposure of animals to human, increase the amount of poaching and exposure to diseases harbored by domesticated species. They also negate the quarantine advantage inherent in a system of isolated biotopes especially reserves (Soule and Simberloff 1986).

Scientific validation of the island biogeography theory (as well as the idea of biotope connection - see below) is still fairly weak. Only for a very small part of the many thousands of plant and animal species of the earth do we know their dispersal ecology, minimal habitat area and dispersal distance.

An important biological feature described in the context of population dynamics is the "metapopulation" introduced by Levins in 1970 (see Merriam 1984, 1989, Opdam 1988). Levins considered a set of sub-populations actively in contact with each other forming a population on a higher level of organization. The **metapopulation** represents the concept of interrelationships between sub-populations in more or less isolated patches.

Many species naturally and especially in cultural landscapes occur in populations that are separated to varying degrees by poorer quality habitat. In fragmented landscapes the remaining patches of biotopes are too small to guarantee a sufficient chance of survival alone. Small populations are particularly sensitive to population, genetic change and environmental fluctuation, and local extinction may be a regular occurrence. For these populations, survival can depend upon interaction with other nearby populations.

The concept of the metapopulation offers a theoretical framework for structuring research and ideas on populations in fragmented landscapes. It stresses the dynamic aspect, caused by the opposite effects of extinction of subpopulations and recolonization of empty patches. Evidence from the literature supports the presented model of a metapopulation in qualitative terms (Opdam 1988):

- species distribution in a fragmented landscape is dynamic,
- extinction and recolonization are frequent events,
- often, some patches, mostly the small and isolated ones, remain unoccupied for one to several years.

The metapopulation model, however, is often based on simplified assumptions regarding the distribution of habitat and the search for suitable habitat (random dispersal). Many species of conservation concern have limited demographic potential and these species may be at greater risk from habitat loss and fragmentation than previously suspected (With and King 1999).

In this context, the species-specific **active radius of animals** (see Table 2.8-1) is important. Among others, the following questions are of interest: Can the distances between isolated habitats be bridged (e.g. by amphibians to their spawning ground)? How far do predators and entomophagus parasites penetrate from adjacent woods to arable fields? These problems are mentioned by Aldo Leopold in his book "Game management": "The game must usually be able to reach each of the essential types each day. The maximum population of any given piece of land depends, therefore, not only on its environmental types or composition, but also on the interspersion of these types in relation to the cruising radius of the species. Composition and interspersion are thus the two principal determinants of potential abundance on the game range. Management of game range is largely a matter of determining the environmental requirements and cruising radius of the possible species of game, and then manipulating the composition and interspersion of types on the land, so as to increase the density of its game population." (Leopold 1933 in Rolstad 1999).

Table 2.8-1: Active radius of some carnivorous animals (from Müller1981)

animal	active radius
ants, carabid beetles, red-backed shrike	50 m
toad, mouse-weasel	150 m
shrews	200 m
hedgehog	250 m
ermine	300 m
fox	1000 m

Dispersal of organisms in landscapes can be hindered by **barriers** which cause or increase the isolation (see Chapter 2.5.3). In **natural landscapes**, mainly rivers prove to be barriers. Their isolating effectiveness increases with their width. Many animals can overcome a narrow rivulet without any problems. Still easier, plant seeds can be carried by wind, or animals over such obstacles. A broad lowland stream, however, isolates the populations at both sides much more. The intensity of the barrier function depends on the type of species. Waterfowl and birds at all are able to overcome the distance between isolated habitats much better than amphibians, butterflies better than isopods, spiders or even snails.

Today, the separating effect of running waters is low compared to other **human barriers**. Increasingly, artificial barriers such as roads (from narrow streets up to highways), tracks in fields and forests, railways, power lines, channels, fences and walls cause landscape fragmentation. On average, 2.1 km roads, 0.1 km railways and 1.4 km sealed tracks cross every km^2 of the territory of Germany. If the traditional routes of amphibians are crossed by a newly built road, the whole population can become extinct within only a few years. Barrier effects of tracks have been established for mice, carabid beetles, spiders and esp. snails (Mader and Pauritsch 1981).

2.8.3 The minimum area

Species sensitive to habitat size and are called "area-sensitive". Thus, there are animal species demanding large compact forests with old-growth stands, e.g. the forest-interior breeding Tengmalm's Owl *(Aegolius funereus).* Another example, the Curlew *(Numenius arquata)* as a synanthropic species, need large areas of mesotrophic and moist grassland which is not structured by wood patches. If motorways, forests or other unsuitable landscape elements subdivide the area, the remaining partial habitats can be too small and the species disappears. An enrichment of the agricultural landscape by hedgerows and coppices can also be unfavorable for other species, such as the Great Bustard *(Otis tarda).*

The "minimum area" characterizes the size of the area (habitat) which an organism needs for survival. Generally, we must distinguish between the minimum area of an individual, a population and the total species (Heydemann 1981). The last contains, as a rule, several populations in a number of biotopes of one biotope type. Only if these populations are in contact, there genetic exchange, ecological adaptation to varying environmental conditions and thus a good chance for long-term survival can be realized (see the concept of metapopulation above).

The lack of reliable data concerning minimum areas (and other ecological demands) for most species is a shortcoming of this concept.

Many animal species need a pattern of different biotopes, so-called **biotope-complexes** (see Chapter 3.2.8) The chance of achieving a description, of the demands of our native species on the size and structure of their habitats, is small (Blab 1992). Existing **data** concerning minimum areas (Tables 2.8-2 and 2.8-3) is rule of thumb. It is better to consider such data than working without data at all.

Table 2.8-2: Minimal areas of animal populations (from Heydemann 1981)

group of animals	minimal area
microfauna, soil (up to 0.3 mm)	< 1 ha
mesofauna, soil (0.3-1 mm)	1-5 ha
macrofauna A (invertebrates, 1-10 mm)	5-10 ha
macrofauna B (invertebrates, 10-50 mm)	
sessil spieces	5-10 ha
species (active movement on land)	10-20 ha
species (active movement through air)	50-100 ha
megafauna A	
small mammals	10-20 ha
reptiles	20-100 ha
small birds	20-100 ha
megafauna B: big mammals and birds	100-10,000 ha

Table 2.8-3: Minimal areas, maximal distances and critical sizes of populations (according to Heydemann 1981, Jedicke 1994, Mader 1981, Reichholf 1987, von Haaren 1993)

E - minimal area of the ecosystem or biotope type; **S** - minimal area of a brood pair or a single individual; **PZ** - necessary population size; **MP** - minimal area of a population; **DH** - maximal distance between partial habitats; **MDP** - maximal distance between minimal areas of populations; **BP** - brood pair

biotope type,animal species	E	S	PZ	MP	DH	MDP
standing waters (ponds)	10m² -1ha				some	
amphibians			100	100 m	100 m	2 - 3 km
oligotrophic lakes	100 ha					
running waters	5 - 10 km					
kingfisher, gray wagtail, dipper, fishes				5-10 km	5 km	5 km
riverside strips	5 - 10 m					
moist grassland	10 ha					
curlew		25 ha	10 BP	250 ha	2 km	10-30 km
white stork		200 ha	30 BP		10 km	
snipe		1 ha	10 BP	10 ha	2 km	10-30 km
butterflies				1 ha	100 m	2-3 km
grasshoppers				1 ha	100 m	1-2 km
grass frog				200 ha		
field margins	5 – 8 ha breadth: 20 - 30 m (fauna), ca. 3 m (flora)					
dry meadows	3 ha			3 ha	100 m	1 - 3 km
many butterflies, field-cricket, bumble bee				50 ha		
gravel and sand pits						
sand martin, lizard				1 ha		1 - 3 km
hedges	5-10 m 10-80m/ha		10 BP	10 km		
small birds					100-200m	5 -10 km
herbaceous edges	1-2m broad					
woods						
small birds				5 - 10 ha	100-200m	5 - 10 km
forest biotopes	> 10 ha*					
common viper				1000 ha		5 km
roe-deer		7 - 15 ha				
spiders				10 ha		
carabid beetles				2 - 3 ha		
snails				0.05 ha		
small mammals				10-20 ha		
black woodpecker, tawny owl		> 200 ha				
medium-sized birds				1 000 ha		5 - 10 km
capercaillie				5 000 ha		
old wood plots	1-3 ha					
forest's edges (breadth)	> 10m					
herb edges at forests	> 10 m					
moors, heaths	100 ha					

* for the long-term survival of forest species and communities at least 500 ha are necessary

The fact that with increasing area an increasing number of species is usually present has been explained in three ways. Firstly, a larger area of remnant habitat contains a greater "sample" of the original habitat. Secondly, more species are able to maintain viable populations than in a smaller area. Thirdly, with increasing area there is usually a greater diversity of habitats for animals to occupy. In addition to area and diversity of habitats, however, other factors such as the spatial and temporal isolation of the remnant, and the degree of disturbance, also influence the number of species that are present (Bennett 1990).

The relationship between the area of a habitat and the number of species can be described by **species-area curves**: i.e. a logarithmic curve which rises at first steeply then becomes flat and finally approaches the maximum asymptotically.

The species-area curve can be presented in a simple logarithmic manner: $y = b * \lg x + a$, e.g. by Cieslak (1985) for the number of bird species in woodlots in Poland, or by Vizyová (1985) for urban woodlots as islands for land vertebrates in Slovakia; or in a double-logarithmic form: $\lg y = d * \lg y + \lg c$ or $\ln y = d * \ln x + \ln c$, e.g. Opdam et al. (1984) in isolation studies on woodland birds in the Netherlands.

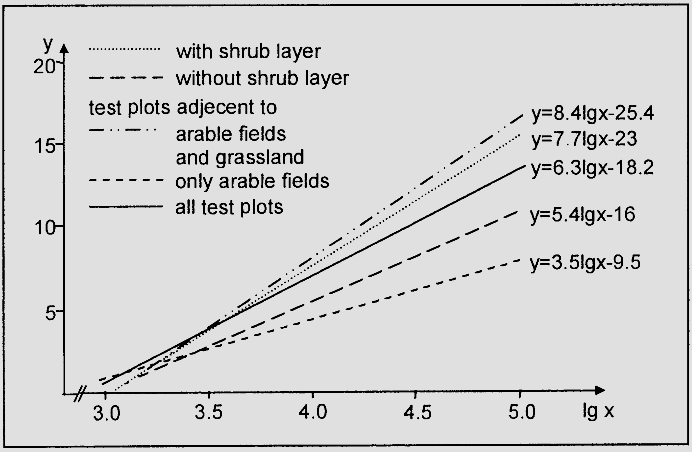


Figure 2.8-2: Dependence of breeding bird species number on forest island area in ruderal landscape near Moritzburg 1986 (from Bastian 1990)

Both models were applied in a case study in the Moritzburg small hilly area (Saxony, Germany). The test area is predominantly in agricultural use, mainly the dry, stony hills are covered by forest islands. A statistically founded dependence of the number of breeding bird species on the size of these woodlots could be proved (Bastian et al. 1989, Bastian 1990, Figure 2.8-2). It also could be established that the forest type, tree species, the presence or absence of a shrub layer within the woods and of the land cover in the neighborhood influences this dependency.

2.8.4 Connectivity and biotope networks

Dealing with the interactions among landscape elements the concepts of connectedness and connectivity have emerged. These concepts are useful in landscape theory as well as in design and management of landscape systems (e.g. Barr and Petite 2001). Connectivity and connectedness are two attributes of heterogeneous landscapes.

Connectedness is the degree of physical connection between patches (landscape elements). It is a structural attribute of a landscape and can be mapped. Connectedness is described in terms of patch size, distances between patches of the same type, presence of corridors (e.g. hedgerows, riparian strips, road margins etc.), frequency of various types of hedgerow intersections and mesh size of hedgerow networks (Baudry and Merriam 1988).

Connectivity is defined as "a parameter of the interconnection of functionally related elements of a landscape so that species can move among them" (Merriam 1984, see Chapter 2.3.6). In contrast to connectedness, connectivity is a more functional parameter. It is a measure of the ability of a species to move between two habitats. The functional connectivity of a corridor does not depend only on its spatial continuity, but also on factors such as life history, population features and behavior of the species utilizing the corridor, the scale of the species movement, its response to the width and the quality of habitat in the corridor. Chance can be important, too. According to Baudry and Merriam (1988) this concept can also encompass other processes such as sub-units of nutrient pools interconnected by fluxes into a landscape nutrient pool.

There are **different types of connectedness/connectivity** (Heydemann 1986):

a) direct contacts within one or between different species:
   - organisms within one population of a species,
   - between different populations of the same species in different habitats,
   - between different species in the same habitat (e.g. food chains),
   - between different species in different habitats (also food chains).

b) direct contacts (connectedness) between ecosystems (biotopes):
   - partly isolated biotopes of the same type,
   - ecosystems of a succession chain (e.g. reed - moist tall herbaceous vegetation - swamp forest),

   - related ecosystems, e.g. semiarid grassland and dry heath, arable land and field margin,
   - ecosystems with low relationship, e.g. arable field and hedgerow, rivulet and shrubs on valley slopes.

c) indirect contacts between ecosystems (biotopes):
   - ecosystems separated by barriers e.g. two partial habitats of birds which are separated by a river.

Landscapes with high connectivity can increase the survival probability of isolated populations. However, according to Zonneveld (1995) one should be aware that the main law of ecology, "not too much, not too little, just enough", is held to be true also for connectivity. So a metapopulation may benefit by high connectivity and become a strong competitor.

Many authors stress the importance of **corridors** between habitats and nature reserves for facilitating gene flow and dispersal of individuals. This can decrease the rate of extinction of semi-isolated groups, increase the effective size of the populations, and increase the recolonization rate of extinct patches (Soule and Simberloff 1986).

There is, however, little evidence that animals use structured corridors such as hedgerows and fences. The same is true for many plants that for dispersion, germination and growth need soil conditions that cannot be assured by a narrow belt of vegetation (Farina 1998). Some species are enhanced by linear elements that act as corridors, some are stopped by the same elements that act as barriers, and some react at such a scale that they do not perceive these elements, either because they are too small and do not move, or because they are highly mobile. Even if studied populations use corridors, the corridor efficiency is not universal. Vegetation structure (herb, shrub and tree layer), corridor width, edge structure, even species composition, are important. The presence of corridors does not necessarily ensure species movement, due to the poor corridor quality (a species dependent parameter) or poor species mobility. More field research and modeling is needed in order to provide more detailed advice to planners and managers. Migration can lead to destabilization and extinction if newly established populations have an effect of a sink, and individuals are "sucked away" from the remnant populations. Corridors may be harmful for a species, because individuals concentrate on this route and attract predators. Last, but not least, corridors my also enhance the movement of pests or diseases across a landscape.

MacArthur and Wilson (1967) emphasized the potential importance of small islands as **stepping stones** between large islands or mainland islands.

Many of the objectives of nature conservation and amenity planning can be realized by developing **ecological networks and greenways**. Acceptance of this idea among national, regional and local governments is growing in both Europe and the USA (Ahern 1999, Arts et al. 1995, Jongman 1995, see Chapter 7.7.5).

For example, the concept of **Territorial System of Landscape Ecological Stability** (TSLES) was developed in the former Czechoslovakia (Buček and Lacina 1985, Doms et al. 1995). It is applied to spatial planning there, and in other countries, such as Mexico (Kremsa 1999). TSLES is built by a network of ecologically important landscape segments purposefully located according to functional and spatial criteria. Such landscape segments (linear communities, elements, districts and regions) have a higher inner stability and are judged according to their biogeographic importance based on evaluating representative and unique natural landscape phenomena (local, regional, supraregional, provincial and biospheric). The most important parts of TSLES are biocenters: both, representative (typical ecosystems of a certain ecological or biogeographic unit) and unique (special ecosystems originating due to specific ecotope properties or specific human influences). Biological centers are connected by biocorridors, enable flow of energy, matter and information. Buffer zones are supposed to prevent negative human influences.

2.8.5 Edge biotopes

Ecotones (see Chapters 2.3.2 and 2.5) are often characterized by a catena of) different environmental respectively site conditions, and by special species combinations of plants (Table 2.8-4) and animals. These ecological conditions often lead to an above average richness in species. This phenomenon is called an **edge-effect**.

Table 2.8-4: Landscape elements with edge character and selected specific vegetation units

landscape elements	vegetation units
sea coasts	*Salicornia* coastal flat-communities
	shore dune-communities
margins / shores at standing waters	*Phragmites*- and *Glyceria*-reeds
	willow-riparian woods and shrubs
	alder swamps
	bur-marigold (*Bidens*)-riparian edges
	Petasites-riparian communities
	Littorella-communities
way- and roadsides	moist and fresh meadow edges
	rocket- and orache-communities
	tansy- and mugwort-communities
forest edges	shrub-communities
	hawthorn-sloe-hedges
	stinging nettle-ground elder-communities
	thermophilic herbaceous communities

The quality of edge zones is markedly different from interior zones, especially with regard to microclimatic parameters and consequently vegetation structure. These differences in habitat quality have strong influence on the species richness and composition (Mader 1980, Ringler 1981). Classical **edge biotopes** are field margins, banks, railroad embankments, but especially hedgerows and the edges of woods. The last represent a contact zone between the dark, cool and moist forest interior to the warmer, drier and windier open area.

The **width of an edge** depends on the species considered, the angle of insolation (latitude) and the main wind direction. The relation between edge and core zone is determined by the size and the shape of a biotope: smaller biotopes have almost totally the character of an edge, compact biotopes have a larger core zone than long biotopes (Forman 1981). For Mader (1980) a decrease in the diameter of a forest below 80 m means that the whole forest consists basically of edge habitat. This lack of forest core area changes the species composition noticeably.

In a further case study in the already mentioned Moritzburg small hill landscape (Bastian 1990) a species inventory of vascular plants was carried out in 48 woodlots (0.012 up to 8.5 ha size). A total of 191 species were found. The share of typical forest species grew with the size of woodlots ($y = 9.9 \lg x - 6.7$). The number of species was related to the size of the woodlots ($y = 29.3 \lg x - 50.1$). Compared with their small size, shrub habitats and hedgerows (*Crataego-Prunion spinosae*) are very rich in species. In total,110 species (58%) were registered only in the edge zones, 18 (9%) only in the interior, and 63 (33%) both in the edge and the interior.

Chapter 3

Landscape analysis, synthesis, and diagnosis

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3.1 Approaches and methods of landscape diagnosis

3.1.1 Introduction

The current land use processes and land use changes in the last centuries make it necessary for all natural, socio-economic and cultural conditions to be carefully considered in the socio-economically dominated processes of landscape management and planning. The socially necessary benefit-cost ratio of securing natural processes of regulation in physical regions, especially for both simple and extended reproduction of natural conditions, is increasingly becoming a driving force in the determination of the economic and social effectiveness of land use.

Extensive and intensive use of processes, functions and characteristics of the physical or natural resources can be accomplished without major disturbances only if the utilization requirements and the existing natural equipment develop proportionally to each other. These proportions are results of, on the one hand, active technical and natural principles (properties of natural-technical geo-ecosystems) and on the other hand, the socio-economic conditions and requirements under which the activities of society are taking place in landscapes, respectively (including urbanized areas).

3.1.2 The social requirements of landscape utilization

A major obstacle to interpreting the results of landscape inventory with respect to utilization requirements is an inadequate theoretical and methodo-

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logical basis. Neef (1969) referred to the combination of scientific exploration results and measurements with technical and economic parameters. He proposed the transformation of geo-synergetic and ecological parameters into economic and social indices. Hence he introduced the term **transformation problem** (see Chapter 5.3, Figure 3.1-1).

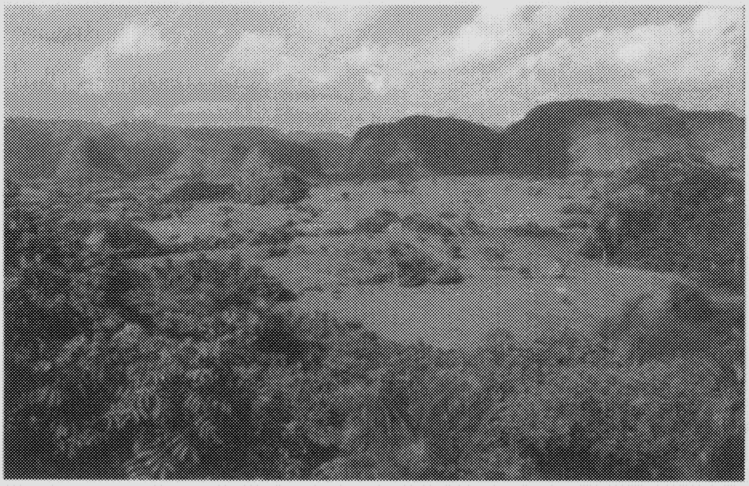

Figure 3.1-1: The transformation of ecological parameters into economic and social indices is one of the central problems in the field of landscape research: Cultural landscape in the temperate tropics – Viñales (Cuba) (Photo: O. Bastian 1993)

A prerequisite for a socially (and economically) precise formulation of landscape management requirements is a multi-part logical chain of relations between landscape inventory and the application of its results to natural resources-oriented planning. According to Graf (1984) the following factors will serve as links:

- criteria for landscape utilization, that have to be fixed by planning authorities and law enforcement agencies (local/regional/national authorities and stakeholders) and that can be measured with respect to social effectiveness and/or economy-related efficiencies (costs),
- criteria-related interpretation of exploration results by means of landscape inventory and (digital) landscape mapping.

The relations between landscape exploration and evaluation and the decisions concerning their utilization have been superposed or even interrupted by other decision criteria. These are the utilization of areas in connection with a further division of labor and with a combination of the social reproduction process as well as financial considerations dictated by the economic utilization of fixed assets funds. Sometimes, this is connected with political transitions as well (e.g. Eastern and Central East Europe after 1990).

Hence it is obvious that the social and/or economic requirements of a diagnostic and prognostic landscape evaluation have to be derived from

- normative target formulations for effectiveness of the specific utilization form, especially for mesoscale analysis (chorological dimension),
- the respective regional utilization structure (represented in land use scenarios, Meyer et al. 2000), and
- the landscape capacities and potentials themselves (Figures 3.1-2 and 3.1-3, see Chapter 5.2).

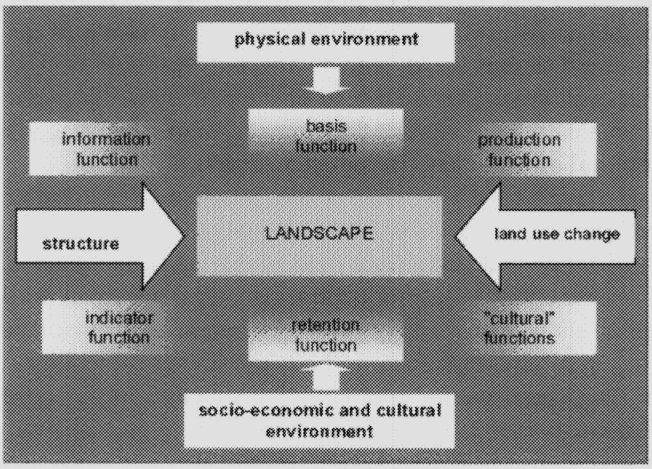

Figure 3.1-2: Landscape functions representing the satisfaction of socio-economic benefits by the natural environment

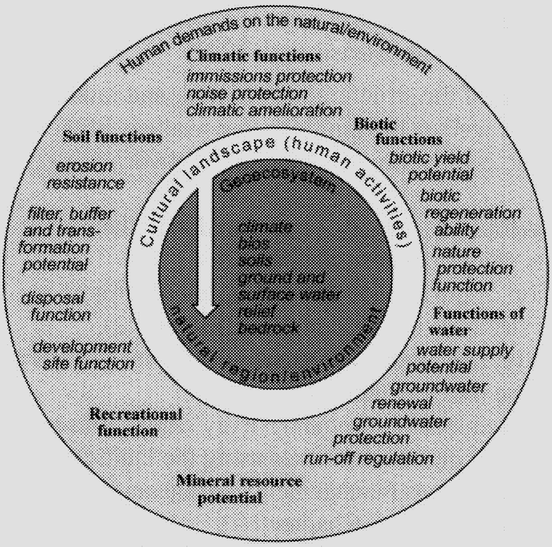

Figure 3.1-3: Functions and potentials of the natural environment together determining the carrying capacity of the landscape (after Zepp 1994 (Klink after Zepp 1994)

The land use efficiency expressing the totality of regional correlation between nature and society is governed, at least theoretically, by the whole amount of socio-economic needs that can be satisfied with the aid of the considered area and its natural potential. This whole amount of social needs and functions is, however, extremely difficult to ascertain. The various needs cannot be determined directly or compared by a uniform measure. The degree of multiple utilization with all its secondary, cumulative, and side effects is hard to determine. Moreover, the different social costs corresponding to the particular efficiency and to local relations of individual land use units have to be allocated or apportioned for the various forms of land use and, finally, for the different scales (Steinhardt and Volk 1999). Therefore it is evident that economic criteria have to be supplemented by social as well as ecological evaluation measures. This way of landscape diagnosis leads to **multifunctional approaches** (Brandt et al. 2000).

Thus it is necessary to consider the following relationship in detail: Landscape is not improved or changed as a whole, but primarily through the utilization of individual parts (e.g. field plots, landscape elements or compartments) or functions (e.g. production, retention, information) demarcated by different users. Consequently, all criteria required for maintaining multifunctionality of a landscape have to be taken into consideration. Any intervention in the overall natural and land use structure has to consider **landscape as an entity** (see Chapter 1.3). At the same time a historical perspective of the landscape marked by major shifts in the time and/or space is necessary.

Geo-scientists and experts of related disciplines attempted to explain and illustrate some approaches to determine the social functions guided by **normative regulations**. It is pertinent to mention some literature published in the former German Democratic Republic (Haase et al. 1991):

– methodological fundamentals of the structural, functional, and interference analysis of landscape as well as the multiple-step analysis of the economic and non-economic evaluation of interactions between society and nature,
– characterization of the development stages of a region due to the social utilization of nature and its consequences (see Chapter 4.1),
– derivation and interpretation of the natural potential as a basis for an assessment of the resources' structure in a region (see Chapter 5.2),
– determination of the stability, resilience, and carrying capacity as parts of an intensively used landscape (see Chapter 5.1),
– methods of transferring landscape inventory and survey results into landscape planning and control of economic branches using the landscape (agriculture, forestry, water resources management, sewage and refuse disposal services, building industry) (see Chapter 7.3),

- methods of the multi-functional assessment of landscape benefits, suitability, and resilience by an optimization approach (see Chapter 5.4).

Based on these facts it is obvious to start a **landscape analysis** from one of the following two premises:

1. Dealing with problems associated with resources available to society a **landscape approach** is essential. The major focus has to be on the landscape capacity and its limiting conditions and risk factors.
2. Dealing with problems associated with resources available to society a **reproduction-area approach** is essential. It has to start from the actual land use and has to include the potential abilities and incompatibilities.

A detailed description of the landscape's functions in the process of social reproduction is a prerequisite to any attempt including the actual state of landscape. Literature offers several approaches, some of which should be mentioned as typical examples (see Chapter 5.2):

- It is in the sense of a landscape approach that Preobraženskij (1980, 1981) proceeds from the natural functions of a landscape, determining their importance for the process of social reproduction. Haber (1979b) applies the results of bio-ecological research to discriminate between productive and protective ecosystems corresponding to two different behavior patterns of society, referred as "strategy of utilization".
- Using the reproduction-region approach, Niemann (1977) characterizes the social functions of landscape elements and units starting from four functional groups (production functions, environmental functions, human-ecological functions, ethic and aesthetic functions).
- A similar breakdown of the social functions and, consequently, of the social requirements of landscapes is presented by van der Maarel and Dauvellier (1978) in the well-known "Globaal Ekologisch Model" of the Netherlands. Like Niemann (1977) the authors further subdivide the mentioned functional groups to visualize relations between social requirements, landscape structure or natural conditions (see Chapter 5.2).
- Another approach was chosen by Grabaum et al. (1999) using a multicriteria optimization considering compromises between the different land uses and landscape functions (Meyer et al. 2000, see Chapter 5.4).

3.1.3 Principles of landscape diagnosis on the basis of ecological data

Over the last few years, landscape research resulted in the development of an essentially coherent, highly consistent concept of landscape analysis, diagnosis and management (Haase 1991, 1999, Figure 3.1-4).

Landscape analysis can be classified as the first step in this scheme. It results in a scientific landscape inventory with respect to its natural, use-related, and dynamic characteristics. Based upon these results, landscape diagnosis has to determine the "capability" or "capacity" of a landscape to meet various social and economic requirements and to define limiting or standard values. **Landscape diagnosis** lays the foundations for measures taken to improve, to change, and protect landscapes as a whole or some of their components. Depending upon particular social objectives to be achieved, four fields of activity can be distinguished:

- **landscape planning** (preparation and territorial integration as well as securing of suitable measures, see Chapter 7.3),
- **landscape preservation** (conservation and stabilization of natural conditions, structures and species, see Chapter 7.7),
- **landscape control/monitoring** (socially necessary or desirable control of landscape processes, Brandt 2000b, Haase 2000, see Chapter 4.2), and
- **landscape management** (land use strategies).

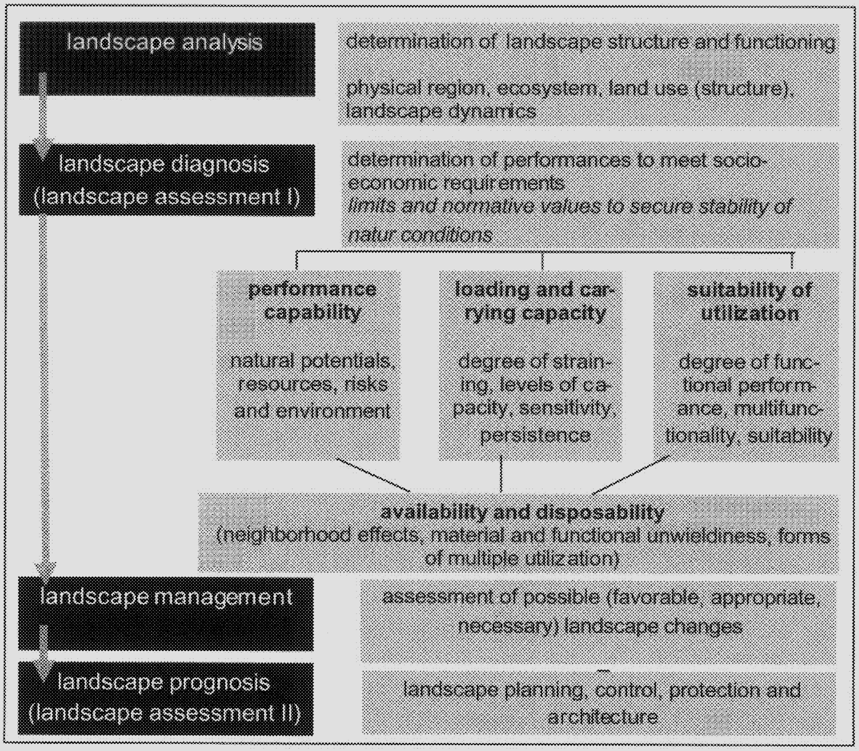

Figure 3.1-4: Interrelations and connections between landscape analysis, diagnosis and landscape management (Haase 1991)

The following four-phase approach based on a detailed landscape analysis is the methodological base of landscape diagnosis:

1. **Analysis of the social functions** of landscape considering also future land use types.
2. **Evaluation of geo- and bio-ecological landscape characteristics** (determined by laws of nature) with respect to socio-economic requirements and functions.
3. **Analysis of landscape interactions** including secondary and remote effects as well as limitations triggered by past, present and proposed land use forms.
4. **Social evaluation** of present and proposed land use forms referring to land use conflicts and preparing solution strategies.

This multi-phase approach can be considered as a general model for landscape diagnosis and derivation of prognostic data (Figure 3.1-5). The first phase of landscape diagnosis has already been discussed at the beginning of this chapter and will be explained in Chapter 5.2 more comprehensively. The second phase is based upon a scientific analysis of the spatial structures and the temporal behavior of landscape objects. The third phase requires a connection of scientific information with statements about current and future social utilization. Referring to these criteria as structural diversity, duration and temporal sequence or succession of land use, social expenditures for the reproduction of natural systems, and substitution of substances and processes in the framework of social reproduction can be used.

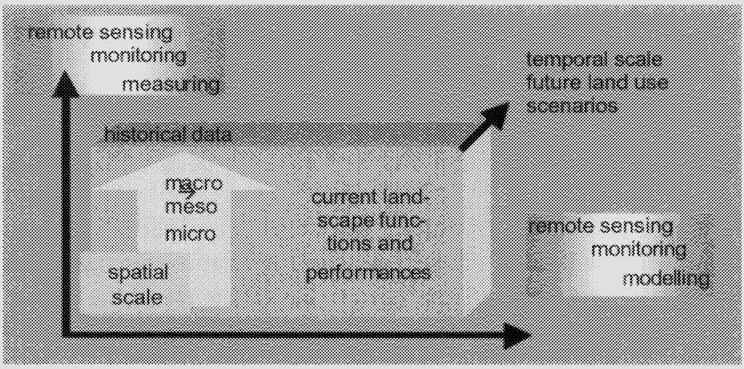

Figure 3.1- 5: Scales and methods for landscape diagnosis

Difficulties are frequently encountered in this particular step: Natural scientists fear of a loss of accuracy and quantitative details. The transformation of geo- and bio-ecological data does not naturally result in scientific accuracy. The connection of these parameters with those of socially determined processes enables information obtained at a more complex level of reality. The more complex and complicated the subject being dealt with, the larger the number of generalized "macro-parameters", transformation functions, tolerance ranges, probabilities, etc. to be used for the resolution. Up to now this problem has not been solved successfully with the exception of some pedotransfer functions with respect to the scale problem (Steinhardt and Volk 1999).

The **comparison of scientific data with** socially determined **standard values** connects causal-analytic and functional-analytic data obtained from the two previously discussed phases of landscape diagnosis with the fourth phase of landscape diagnosis.

There is the demand to translate the scientific data and content in the language of stakeholders and policy goals. At the moment landscape models in form of DPSIR (Driving forces – Pressures – State – Impact – Response) are discussed (Brandt 2000b).

The multistage character of landscape diagnosis can be summarized:

1. Scientific and technological characterization of landscape objects and processes (**scientific and technological stage** of landscape diagnosis).
2. Arrangement of landscape objects and processes into the fulfillment of social functions (**social and function stage** at the regional level).
3. Formulation or verification of standards and norms for use of information in the management and planning of the national or regional economy (**normative stage**).

3.1.4 Aspects of landscape diagnosis and methodological approaches

In determining landscape capacities with respect to social requirements, landscape diagnosis relies on a relatively wide spectrum of cause-effect relations between the natural system and its forms of social utilization (Figure 3.1-1).

With respect to the use of natural resources two aspects which are frequently compared with each other in an opposite relationship have to be emphasized: the resources-related approach to the **efficiency** of the natural conditions as well as the matter and energetic approach to the **resilience and carrying capacity** of natural conditions under certain forms of utilization (see Chapter 5.1). An approach is needed that unifies these two aspects.

Each of the aspects of landscape diagnosis can be described by specific properties that can be determined by a number of proven methods and attributes:

1. Characterizing the **efficiency of natural conditions** through

- determination of properties of the partial potentials and of the natural resources for landscape objects,
- properties of the natural "milieu", especially with respect to the values of human-ecological environment and recreation capability of landscape objects, and
- determination of natural risks (hazards, disturbance factors) in certain forms of utilization for landscape objects and natural processes.

2. Characterizing the **loading and carrying capacities** through
   - degrees of stress and levels of loading capacity, retention time intervals relative to certain forms of utilization, for landscape objects and natural processes,
   - carrying capacity (e.g. acid neutralization capacity (ANC), water carrying capacity, soil density) and limits of carrying capacity, relative to certain land use forms, for landscape objects and natural processes, and
   - characteristics of persistence and sensitivity of landscape objects and natural processes toward certain forms of utilization (modified carrying capacities).
3. Characterizing the **utilization suitability** (Figure 3.1-6) through
   - degrees of functional efficiency and performance of landscape objects,
   - multiple functions of landscape objects (scales of functions, combinations of characteristic features in a multidimensional space),
   - suitability preferences of landscape objects for different social and economic functions, and
   - connection with the history of human activities in a region to determine the development of the cultural landscape and to widen the knowledge about the time-relationship of landscapes processes.
4. Characterization of **availability** (**spatial disposability**) through
   - features of neighborhood effects of pairs and patterns of landscape objects,
   - forms of multiple utilization and their functional modes for landscape objects,
   - gradations of difficulty in the manageability of land use forms in respect of spatial effects of natural processes and neighborhood effects of particular forms of utilization of land.

An expansion of the conventional scientific approach to parameter and attribute transformation is associated with the interpretation of the results of inventory and survey of physical regions and landscape analysis. This is based on the proposed objectives to be tuned to the decision process on usually highly complex subjects, which are intended to be included.

Figure 3.1-6: Characterization of the landscape's suitability for utilization is a main issue in landscape diagnosis. The preferable agricultural use of moist lowlands is perennial grassland: Lowlands of the Havel River with pruned willows (Brandenburg, Germany) (Photo: O. Bastian 1998)

At the current stage of modern landscape ecology as an applied science the following methodological approaches seem to be the core of managing the process of landscape diagnosis in a complex synthesis:

- remote sensing as a tool for landscape evaluation (see Chapter 6.3),
- Geoinformation Systems (see Chapter 6.2),
- methods determining the structural properties of landscapes or landscape pattern (see Chapter 6.2),
- theory of fuzzy sets or fuzzy logic and
- modeling approaches to simulate landscape functioning depending on the different landscape components and processes (see Chapter 6.4).

The solution of methodological problems in interpreting landscape structures has received strong impulses from operation research, system engineering, and economics of natural resources or **landscape economics** (Bechmann 1978). At present there are only initial approaches available to a consistent methodology. Participation in the development is among the major tasks to be accomplished by landscape research in the next couple of years (see Chapter 7.12).

3.2 Landscape analysis: investigation of geocomponents

The high complexity of landscape structures and the interaction of ecological processes means analysis has to be extremely thorough. The two types of analysis used are differential analysis, which addresses individual components of the ecosystem. On the one hand there are soil type, pH, soil nutrient content, climatic data or the species composition of the vegetation (Haase 1964), and on the other hand complex site analysis, which is conducted at a higher, integrated level, and chiefly focuses on the vertical interrelations between the various geocomponents (see Chapter 3.4). Complex site analysis can usually only be carried out after differential analysis. A number of important techniques of differential analysis are outlined below (for more details see Barsch et al. 2000, Bastian and Schreiber 1999, Leser and Klink 1988, Zepp and Müller 1999).

3.2.1 Geological structure

The rock structure of a landscape in connection with the surface forms grants insights into the division into natural areas, above all on a medium scale (i.e. chores). Nevertheless, geoecological investigations do not focus primarily on exploring the geological structure and the rock types. The rock is usually an ecologically indirect geofactor. It affects the nutrient and water balance of the soils emerging from it, has a certain water conductance, and resists the forces of erosion depending on its type – a property which is known as the erosion resistance of the rock or soil (see Chapter 5.2).

Knowledge of certain rock properties is essential in order to conclude ecological characteristics. The primary factors are **mineral composition and structure**. Both have an influence – in connection with rock weathering – on the soil forming, its composition, particle structure, and hence water balance. The structure includes characteristics such as the stratification, form, size and crystallization of the minerals, as well as texture (i.e. their arrangement and distribution in space). This is not the place for a detailed examination of rock characteristics and their influence on local ecological conditions. However, Table 3.2-1 lists some of the important ecologically relevant characteristics of the most frequent groups of rocks.

The main **sources of data** are small-scale, complex geological maps and their explanations, such as special geological maps on a scale of 1:25,000. They show the rock which is on the earth's surface, and which hence mainly influences ecological conditions. By contrast, horizon maps show the underground rocks, for instance geological formations located beneath loose sediment or weathering cover. Other maps which can be used as sources of data include thematic geological maps, hydrogeological and engineering-geological maps, tectonic maps and lithofacies maps. Cross-sections and block diagrams provide information about the characteristics of the vertical geological structure.

Table 3.2-1: Characteristics of important rock groups (after Röder, in Bastian and Schreiber 1999) (1 – very high, 2- high, 3 – moderate, 4 – low, 5 – very low)

rock types	potential nutrient supply	potential ground water content	building ground aptitude (stableness)	resistance to soil erosion (by water)
sediments				
clay	1-2	5	4-5	4-5
silt	2	4	3	4-5
sand	3-4	2	2-3	3-4
gravel	4	1	2	3
fens	4	1	5	-
sedimentary rocks				
evaporites	5	5	4-5	5
carbonate rocks	1-2	1-2	2-3	3-4
arcoses, graywackes	2-3	2-3	2	2-3
sandstones	3-4	2	2	2-3
magmatic rocks				
acid	3-4	4-5	1	1
intermediate	2-3	4-5	1	1-2
basic, ultra basic	1	4-5	1-2	2
metamorphic rocks				
quarzitic rocks	3-4	4-5	1	1
phyllites	2	4	2-3	3-4
mica slates	2-3	4	1-2	3
gneiss	3	4	1	2-3
hornfels	3	4-5	1	1

3.2.2 Relief

The relief forms the basis of a landscape's structure. The more pronounced the relief, the more structured and hence divided the landscape, including in ecological terms. Nevertheless, relief is only an ecologically indirect factor – in other words a **regulating factor** (Figure 3.2-1); its influence takes effect via the climate, soil formation, and the water and nutrient supply. Relief influences the air flow, affects the temperatures and precipitation, and also engenders terrain climates. The relief forms are linked to the entire water balance of a landscape. Through the factors mentioned, the relief regulates the composition and distribution of biocoenosis and the possibilities of land usage.

In order to fully survey the ecological regulatory effects of relief, the **surface form** (geomorphography) has to be considered together with the underground area just below the surface (Leser 1997) – after all, the form only becomes ecologically effective in conjunction with the subsurface ground (i.e. the soil including the weathering cover and the rock from which the soil developed). The ecological significance of the underlying rock mainly comprises the type of water conductance and in the case of very flat soils its rooting. The subsurface ground hence determines soil formation, water balance and substance distribution.

Figure 3.2-2 shows the connection between relief forms, spatial structure and geoecological processes. The relief affects the landscape balance via the underground just below the surface and the surface water connected to the relief by means of its position (erosion bases). Owing to its structure-forming, process-regulating effect, all in all **relief plays a key role in ecosystems**.

Figure 3.2-1: The relief is an important regulator of the landscape balance: Alpine landscape of the Dolomites (Southern Tyrol, Italy) (Photo: O. Bastian 1998)

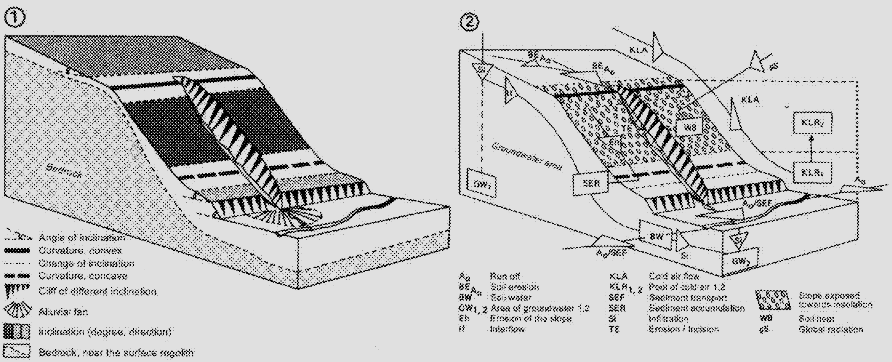

Figure 3.2-2: Geomorphographic characteristics as regulators of the landscape balance (after Leser 1997)

Relief analysis allows physiognomic features of the ecological differentiation of the landscape to be quickly grasped, especially in the case of more pronounced surface forms. Geomorphographic division provides suitable openings for special geoecological investigations of soil forms, soil dynamics, the soil-water balance, and the mesoclimate and microclimate. Assuming the right vegetation, the plant communities themselves are enough to provide an initial estimate of the ecological conditions of the site types connected to certain terrain forms. The first small-scale division into natural areas with landscape ecological aims was therefore geared towards relief (Paffen 1953, Troll 1950).

Relief analysis for landscape ecological purposes starts off with a taxonomic structure of relief areas of differing complexity. Important characteristics include terrain incline, terrain curvature, exposure and position. They are joined by the roughness of surfaces caused by small forms of partly natural, partly anthropogenic genesis. Geomorphological units of varying complexity can be deduced from these determining features. The smallest and simplest geomorphological unit is the **relief facet** (Dikau et al. 1999, Kugler 1974).

A number of relief facets (which often only slightly differ from one another) make up a **relief element**. A relief element is based on a uniform curvature tendency. More detailed features include slope incline, exposure and position, i.e. the position within relief formation. The delineation of relief elements is carried out by means of the areas of curvature. Another determining feature is the roughness of the terrain surface, which may be natural such as in the case of hummocky meadows (caused by frost dynamics), or a result of human activity such as field terraces, rock walls and arched farmland. Relief elements form the main geomorphological basic units in geoecological spatial division and planning.

The connection between adjacent relief element enables higher relief units to be determined, which can be differentiated and characterized in terms of their outline. Relief has a number of characteristic shapes (rounded hill tops, ridges, valleys, etc.) known as **relief forms** (relief types).

Relief complexes of differing degrees of aggregation are constitutive for larger natural areas. One important aspect with repercussions for internal differentiation is the degree of fragmentation (density and depth of valleys) as well as – as in every case – area size.

The land pattern of **slope inclines and curvature** offers important starting-points for identifying physiotopes (geotopes) and ecotopes, especially in hilly areas (Figure 3.2-3). The close correspondence between relief elements and site qualities is due above all to the movement and distribution of soil water and the dissolved and solid substances it transports. Apart from the slope incline and curvature, it is also dependent on the underground just below the surface: the particle structure and any stratification of the soil types and the source rock, as well as the geological underground, as long as it influences the water balance by means of rock density, stratification and crevasse formation. This correspondence of relief elements and ecological site conditions was used for the delineation of geotopes on the basis of areas of curvature (Klink 1966, Paffen 1953, Troll 1950).

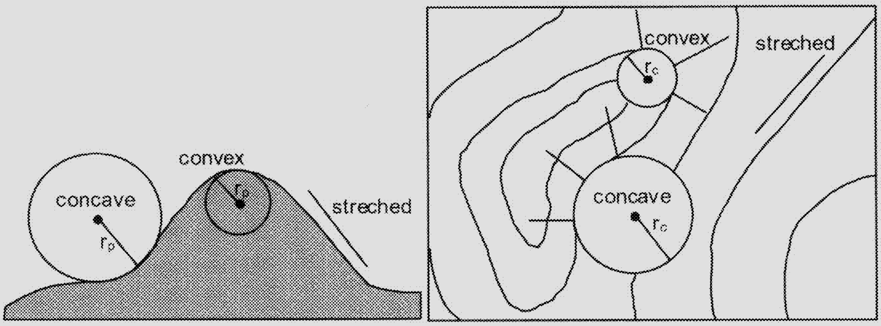

Figure 3.2-3: Correlation between curvature and topographic contour lines (isohypses): profile curvature radius (left) and contour curvature radius with runoff direction (right)

Another important geoecological process parameter connected with relief is **radiation reception**, upon which the formation of topoclimates depends. Radiation reception can be calculated by means of the slope incline and exposure. Calculation for different angles of incline and slope exposure can for example be performed using the cumulative insolation values of Morgen (1957), who compiled this information for a latitude of 50° north.

The mainly water-based material differentiation on slopes results in a regular sequence of different soil forms which is largely parallel with the slopes, and which are linked together by means of processes in a law-based relationship. In geologically uniform areas with certain relief, these **soil sequences** (toposequences) are repeated in typical pattern (Figure 3.2-4). As this relief-related differentiation of the soil also has ecological effects, Haase (1964, 1967) and Klink (1964, 1966) wrote of "ecological catenas", following on from the "catena" used in soil science by Milne (1935) and Vageler (1955) (see Chapter 2.6).

One particular problem of geoecological surveys are the **small individual forms** in which internal ecological differentiation is no longer relevant to landscape ecology, such as closed hollow forms (dolines, potholes), alluvial cones and slope failure. They are regarded as independent geotopes and ecotopes, and are mapped as such. Special surveys during landscape ecological analyses and surveys also require surveys of ecologically relevant morphological processes such as slope failure, debris movements, erosion and accumulation, material movements in dune areas, and fracture edges.

Bastian and Schreiber (1999), Leser and Klink (1988), Zepp and Müller (1999) describe the survey techniques for the relief within landscape ecological analysis in great detail. Proposals for symbols independent of landscape types are also contained in the publications by Leser (1988) and Dikau et al. (1999).

The **slope incline** can provide information concerning promoting or limiting factors for the respective potential characteristics for not only groundwater formation, slope interflow, soil erosion, and cold-air formation and outflow, but also for agriculture and forestry (Hütter 1996, Mannsfeld 1978).

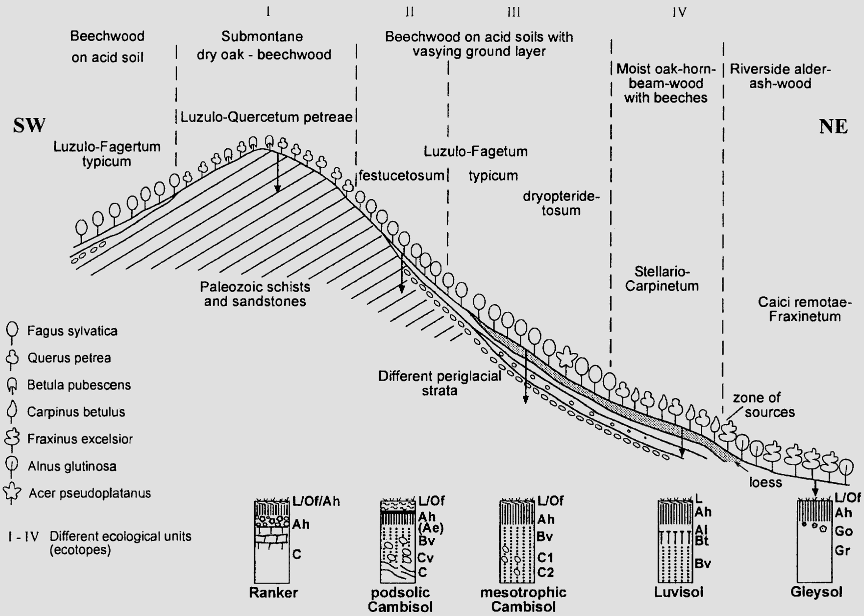

Figure 3.2-4: Typical ecological catena of a hill from the lower part of the Hercynian Uplands (relief sequence)

A mapping technique involving relief forms (form types) developed by Haase (1961) for landscape ecological purposes also enables a picture of the distribution of hollow, full and slope form types to be produced relatively quickly. The form types are surveyed using well reproducible criteria such as length, breadth, height difference, gradient and deepening. This relief analysis results in a **geomorphographic map**, usually on a scale of 1:10,000. The units of area surveyed from a geomorphographic-ecological viewpoint provide a basis not only for aspects of landscape planning and space use, but also for the assessment of geoecological processes such as groundwater formation, soil erosion, cold-air development and outflow, as well as insolation.

3.2.3 Soil

The soil, a more or less thick layer covering loose and consolidated rock, forms the **most important zone of material turnover** of terrestrial ecosystems. It was identified earlier on as an integral feature of a site's ecological conditions and described by Neef et al. (1961) alongside the vegetation and together with the soil water balance as the main ecological feature. This importance applies to the soil's role in the spatial differentiation of landscape ecological conditions (including anthropogenic influences), which is expressed in the spatial mosaic of various soils (pedotope).

By definition, soil is the conversion product of mineral and organic substances mixed with water, air and organisms, which has developed under the influence of environmental conditions, which continues to develop over the course of time, and which has its own morphological organization. The **soil-forming factors** are the source rock, the climate, the local water balance, the relief conditions, life forms (especially soil organisms and plants), and human treatment. The essence of soil formation consists in converting almost chemically inert substances (primary minerals, dead organic matter) into chemically highly reactive substances (secondary clay minerals and humus substances). Owing to mainly water-bound substance differentiation, over time soil horizons form which together make up the soil profile. This is of great diagnostic importance for landscape ecology.

However, as soils only react slowly to changes in environmental influences, soil profiles partly reflect past landscape states. This makes them helpful for research into landscape genesis and cultural history, but also limits their usefulness regarding the current state of the landscape.

Soils perform a number of important **landscape functions** (see Chapter 5.2) and are therefore an important natural asset which needs to be protected. For example, soil is a habitat for the organisms which live in it. These organisms make an important contribution to ecosystem substance turnover (a process known as "biotransformation"). In addition to giving stability to plants whose roots it holds firm, soil also gives plants water, air and nutrients (site function). Owing to their sorbing components, soils contain and convert substances; indeed, the majority of substance turnover in the landscape takes place in the soil cover. This results in the production of plant-available substances while pollutants are broken down (transformation function). Owing to its filtering abilities, the soil is an important substance reservoir (filter and reservoir function). However, not only nutrients but also toxic substances are stored in the soil.

The ability to store substances and hence – at least temporarily – to remove them from the substance cycle is more pronounced in most soils than in the environmental media (landscape components) water and air. According-ing to Schwertmann (1973), the soil is the "substance buffer" of the landscape. The storage and buffer functions are of importance for nearly all soil functions, especially groundwater formation, whose quality largely depends on the passage through the soil of leachate. For example, both heavy metals and toxic organic substances are absorbed by the soil, the latter being partly biologically converted and broken down (biotransformation). However, buffering chiefly means keeping the acid-based ratio in the soil constant. Nutrient availability and the mobilization of fixed heavy metals as well as important soil processes all depend on the acid-base ratio (pH).

The landscape compartment soil is connected to other compartments (water, relief, organisms, the atmosphere) by the transport of water, matter and energy. This is mainly why it so useful as a source of information. Particularly close is the relationship of soil with water (soil water, leachate and groundwater) and organisms, with which it is linked by means of nutrient webs. The soils in a landscape area are subjected to mutual influence by means of lateral substance and energy fluxes. This is expressed in catenas (toposequences and hydrosequences) and soil communities, which are also used as mapping units. The following **primary soil characteristics** can be gauged in the field and the laboratory by standard methods of soil analysis:

- soil form,
- soil structure,
- soil texture,
- soil depth,
- humus content and humus form,
- acid-base ratio (acidity/alkalinity),
- nutrient supply, and
- soil water content.

The ecologically relevant soil characteristics and properties can be divided into stable (barely influencable) and unstable (easily influencable) ones. The group of factors which are difficult to influence include soil type, skeleton fraction, depth and field capacity; the group of factors which are easier to influence include the acid-base ratio (pH), nutrient supply and humus content.

The **soil form** is the general characterization of a soil in terms of soil type and parent rock, i.e. the "substrate-systematic unit" according to AG Boden (1994). The **soil structure** refers to the spatial arrangement of the irregularly formed solid mineral and organic soil components dividing the entire soil volume into the volume of solid soil substance and pore volume (with growing proportions of water and air). Factors which depend on the soil structure include the water, air, heat and nutrient balance, rooting capacity and workability, as well as transfer processes.

The **soil texture** refers to the particle size composition of the mineral soil, with a distinction being drawn between fine soil (particle size up to 2 mm) and coarse soil (soil skeleton with particle diameters exceeding 2 mm). The soil texture is connected to a whole series of structural and regular parameters in the ecosystem. Together with the soil's water balance, the soil texture and soil structure are important parameters for the heat balance, and determine the erosion resistance (water and wind).

Fine soil (i.e. the soil texture) can be classified using the soil texture diagram (Figure 3.2-5). The coarse soil (skeleton fraction) can be classified following on from AG Boden (1994) (Table 3.2-2). For certain applications such as calculating the usable field capacity, it may be helpful to subdivide the entire coarse soil into the fractions breeze/gravel (2–63 mm) and stones/blocks (>63 mm). The granulation of the entire soil then results from the combination of fine and coarse soil.

The **soil skeleton** determines in particular water balance characteristics such as field capacity and water permeability. Consequently, it influences the water storage capacity and the filter capacity. Moreover, nutrients (substances) can be constantly "washed" out of the coarse soil by weathering. On the other hand, the increasing skeleton content reduces not only the proportion of fine soil, but also the usable root area and increases susceptibility to soil erosion.

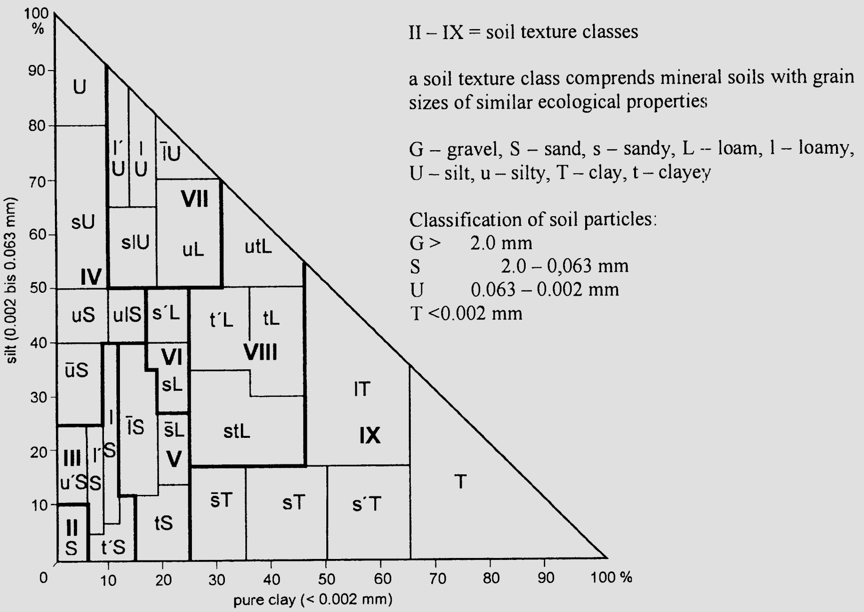

Figure 3.2-5: Soil texture triangle of mineral soil divided into soil texture classes

Table 3.2-2: Classification of coarse soil (skeleton fraction) after AG Boden (1994)

class	indication	portion	
		volume-%	mass-%
1	very slightly stony, gritty	< 2	< 3
2	slightly stony, gritty	2 – 10	3 – 15
3	medium stony, gritty	10 – 25	15 – 40
4	Intense stony, gritty	25 – 50	40 – 60
5	very intense stony, gritty	50 – 75	60 – 85
6	stones, gravel, detritus	> 75	> 85

Bodies of soil often feature an ecologically relevant change in the soil texture or the soil texture class within the profile depth of 1.3 m as a result of soil development processes, periglacial or other geological occurrences, or even anthropogenic activity. When surveying the soil, the **soil texture stratification** i.e. soil types (classes) and the depth at which the soil type changes must then be indicated.

The **soil depth** refers to the thickness of the potential root space, i.e. the volume of soil from which plants can meet their water and nutrient needs, and in which they can stand, enabling them to achieve stability. The soil depth is hence an important parameter within the ecosystem on which the plant-available water and nutrient stocks of a location depend. The soil depth can usually be determined fairly accurately in the field by interpreting the actual rooting density and estimating the rooting scope. The main factors which influence soil depth are consolidation, porosity, aggregation, stone content and the depth to the water table or subterranean water. In the event of soils with a low skeleton fraction, the consolidation throughout the area can be determined fairly precisely by means of penetrometer measurements (Hartge and Horn 1989). The literature also contains information on the exact determination of consolidation using volume samples (Schlichting et al. 1995). Rooting barriers include densely packed soils with substrates with a pore volume below 35 percent.

Soil **humus** refers to all the organic substance in and on the soil. It is subjected to constant processes of breakdown, conversion and development, and also undergoes constant change, including reduction or increase. The humus content of soil is the percentage by weight of humus in dry fine soil. It is usually assessed in the field by simple visual inspection: the higher the humus level, the darker the soil. The main factors of modification are moisture and substrate.

The **humus form** is characterized by a sequence of different layers or horizons containing dead organic substance – partly on the surface, and partly mixed with the mineral soil. Its morphic and chemical properties depend on the type of organic substance, as well as the abiotic decomposition conditions and the activity of the soil organisms as they undergo degradation.

Abiotic decomposition conditions include the climate, moisture and chemical milieu (certain acid-base ratio), which is sharply dominated by the mineral substrate. Moreover, the vegetation (soil cover) and the type of land usage have a strong influence on the humus form. All in all, the humus is a powerful indicator of site conditions, and can also respond rapidly to short-term changes.

A distinction is drawn between dry (aeromorphic) and moist (hydromorphic) humus forms, as well as underwater (subhydric) forms. The main **aeromorphic humus forms** are:

- mull humus: from biotically active soils rich in nutrients. Easily degradable vegetation residues are quickly broken down, humified, and mixed with the mineral body by the soil fauna or soil tilling,
- raw humus: from biotically inactive soils low in nutrients. Poorly degradable vegetation residues form floor humus on top of the mineral soil,
- moder humus: an intermediate product between mull and raw humus.

Hydromorphic humus forms (moist raw humus and muck humus) are created under temporary anaerobic conditions, whereas turf (lowland moor, transition moor and raised bog turf) is formed under conditions of water saturation. Subhydric humus forms (dy, gyttja, sapropel) are formed at the bottom of bodies of water.

The humus is the soil component which exerts the largest influence on processes of soil dynamics and hence the development of organisms living in and on the soil. As far as the ecological functions exercised by the various humic substances in the soil are concerned, a distinction is drawn between nutrient humus and mild humus. **Nutrient humus** comprises substances which are easily susceptible to microbial breakdown. They provide food for migrants and so when broken down release plant-available nutrients (CO_2, N, P, S, mineral substances). By contrast, **mild humus** consists of high-polymer substances which are difficult for migrants to break down. Owing to water bonding, they mainly act as ion exchangers (source and sink function) and are responsible for structure creation in the soil. The source and sink function is important not only for the supply of nutrients, but also for groundwater quality.

The **soil reaction (pH)** controls many development processes in the soil and influences the organisms living on and in the soil. In particular, it influences ecosystems by affecting the following factors:

- composition of the edaphone (the sum of all soil organisms) with respect to the species and quantities occurring, as well as the biotic activity as the sum parameter of the humus form and humus turnover,

- elemental composition of the soil solution and hence the supply of plant-available nutritional elements, as well as the ion composition of soil exchangers (e.g. cation exchange capacity and base saturation),
- bioavailablity of pollutants (e.g. heavy metals),
- material composition of leachate and hence substance discharge, and
- structure formation and aggregate stability caused by the ion composition of the soil solution, and hence the soil's water and air balance.

The **nutrient supply** refers to the supply of substances which are made available by the soil to the plant as "building materials" for their body substance and as "fuel" to maintain their life functions. A distinction is drawn between main nutrient elements (macro-nutrient elements) such as N, P, K, Ca, Mg and Fe, and trace elements (micro-nutrient elements) like Cu, B, Mn, Zn, Mo, Se and Cl. Some of these elements are plant-specific: Cl, for instance, is specific to obligate halophytes. Characterizing the nutrient supply of the soil is normally fairly complex. Generally speaking, soil fertility (which depends on the nutrient supply and the water balance) is determined by the level of sorbable substances and their ion make-up, which in return for H^+ and Al^{3+} ions surrender other ions to the soil solution, making them available to the plant. Such sorbable substances or exchangers include clay minerals, humic substances and to a lesser extent Fe and Al hydroxides.

When considering the soil's nutrient supply, the fraction which can be replenished also needs to be taken into account. It comprises the mineral content and the susceptibility of the source rock to weathering, as well as the level of humus substance in the nutrient humus and its conversion. Humus is the chief source of the main nutrients N and P, especially in natural ecosystems.

Surface sealing is an important factor which needs to be taken into account in soil investigations in urban and industrial ecosystems. It indicates an area which is covered by buildings or by natural or artificial substances. If land is sealed, this partly or totally prevents the exchange of gases and infiltration, and alters important hydrological parameters, hence affecting both the edaphon and metabolic processes. All in all, the partial or total sealing of land upsets important hydrological and substance-balance parameters, and limits or even eradicates its biotope function.

In order to systematize the wide variety of soils, some form of classification is needed. **Soil classification systems** can be compiled using pedogenetic, regional or functional factors. However, they are always based on the extended causal chain of pedogenesis and pedofunction.

Early Russian and North American classification systems, which nowadays are still partly used for large-scale approaches (e.g. ecozones), define soils in terms of their zonality in accordance with climatic and vegetation zones. These **factor-based classification** systems divide soils into zonal, intrazonal, and azonal soils. The main pedogenetic factors taken into account of zonal soils are the climate and vegetation; this is a highly generalized viewpoint. In intrazonal soils, rock and relief influences play the main role in the pedogene (e.g. calcium, salt, soda soils and groundwater soils in low-lands). Azonal soils generally only exhibit weak profile differentiation. Above all colluvial and alluvial soils extend right through climatic zones in the floodplain areas of rivers.

One consistent **taxonomy system** of characterization is "7th approximation", which was developed in 1960 in the USA, and which since 1975 has been known as "soil taxonomy".

In Germany, soils are usually classified using the system developed by Kubiena (1953) and Mückenhausen (1977). It is based on various criteria:

- compartment: the effect of water in the uppermost category,
- class: mainly the general horizon combination, as well as special properties and specific soil dynamics, and
- type: peculiarities of the horizon sequence and specific horizon properties.

The types are divided by qualitative and quantitative modifications into sub-types, varieties and sub-varieties. We distinguish between four compartments:

- terrestrial soils (soils unaffected by groundwater) with eleven classes: virgin soils, A–C soils, steppe soils, pelosols (clay soils), brown soils, podzols (greyish-white soils), terra calcis (soils from carbonate rock), plastosols (plastic soils from silicate rock), latosols (red lateritic soils), colluvia, anthropogenic soils,
- hydromorphic soils (semi-terrestrial soils) with six classes: stagnosols (pseudo-gleys), alluvial soils, groundwater soils (gleys), source water soils, marshy soils, anthropogenic soils,
- sub-hydric soils (underwater soils) with four types: protopedon, gyttja, sapropel, dy, and
- moor soils with two classes: natural and anthropogenic moor soils.

Mainly for work outside Central Europe especially in the tropics, the classification of the **FAO-UNESCO Soil Map of the World** is used.

3.2.4 Soil water/groundwater and surface water

The **soil water** is the fraction of subsurface water which takes the form of specific retention, capillary water or leachate in the soil. Since it undergoes seasonal variation, it performs a regulating function in the landscape. Because it dissolves and transports substances (including nutrients and pollutants), the water balance also controls the substance balance in the soil, which in turn affects the entire ecosystem. The soil water is of special ecological importance. It influences not only plant growth, but also groundwater formation, groundwater protection, the filter potential and the biotic yield potential, and other landscape functions.

It was over 40 years ago that Neef et al. (1961) already realized the importance of **soil water** and the **soil moisture regime** in landscape ecology.

Areas with the same soil moisture regime are referred to as **hydrotopes**, the basic types including leachate-dependent hydrotopes, waterlogging-influenced hydrotopes, groundwater-influenced hydrotopes, slope water influenced hydrotopes, and hydrotopes influenced by groundwater and periodically flooded. Account needs to be taken of not only different soil water dynamics in adjacent sites but also the spatial combination of hydrological neighborhood effects, examples of which include **ecological catenas** (see Chapter 2.6) on slopes and hydro-sequences in valleys.

Ascertaining lateral water fluxes can provide a basis for estimating the type and intensity of the vertical and lateral discharge of substances from the soil into the groundwater and surface water (Zepp 1995, 1999). Via the water cycle, soil water and groundwater interact with adjacent and also more distant landscape areas and their compartments (Wohlrab et al. 1992, see Chapter 2.7).

The following **primary parameters** are measured in the field: water table, degree of waterlogging and slope moisture, and basic type of soil moisture regime. The following are determined using auxiliary variables: ecological degree of moisture, usable field capacity of the effective root space, saturated water permeability, and quantitative soil moisture regime.

The quantitative capture of processes in the landscape water balance such as infiltration, seepage, capillary ascent, root water removal and transpiration calls for measuring equipment in the field supplemented by the laboratory determination of hydraulic parameters and corresponding methods of analysis. In addition to information on the landscape compartments vegetation and atmosphere, such measuring series and parameters form the basis for the dynamic simulation of the water balance of representative areas (ecotopes). They can also be used for regionalization (Duttmann and Mosimann 1994, Feddes et al. 1988, Reiche 1991, Zepp 1995, 1999).

The most important **hydraulic characteristics** of a soil usually determined in the laboratory include water moisture (PF curve), water conductivity in unsaturated soil (kf_u value) and water conductivity in saturated soil (kf value). The moisture tension function is used to derive the soil parameters total pore volume, usable field capacity, air capacity and dead water fraction (Figure 3.2-6).

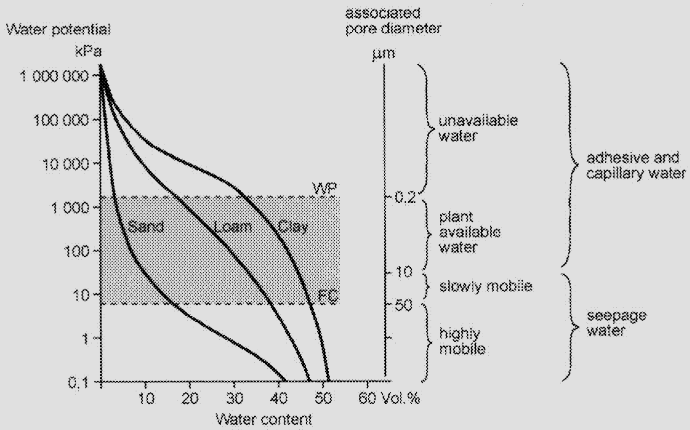

Figure 3.2-6: Soil water parameters

The change in soil water content can be simply and inexpensively measured by gravimetry. TDR technology (time domain reflectory) is used to measure the content of soil water and has replaced the formerly widespread neutron and gamma double probes. Soil moisture can be measured with tensiometers (Hartge and Horn 1989).

The **usable field capacity** and the **saturated water permeability** can be estimated from the soil type strata indicated (Figure 3.2-7). Alternatively, the ecological degree of moisture can be derived from the soil type, stock of groundwater and waterlogging. This procedure is particularly recommended whenever detailed phytosociological surveys have not been carried out.

The list of **indicator values** of central European vascular plants compiled by Ellenberg et al. (1992) is a very useful tool for assessing local water balances in the field (see Chapters 3.2.6 and 3.3).

Hydrological maps are sometimes available as outline maps or small-scale special maps, as well as for certain water catchment areas. The volume of information they contain depends on their scale. Under certain circumstances, **geomorphological maps** can also be used to obtain information on the water balance. It is important that at least small-scale maps (1:25,000 and upwards) contain details of the water tables and the grain size of the water-conducting strata.

Surface waters are diversified ecosystems with high biodiversity, making them extraordinarily important elements of the landscape. **Running waters** (e.g. streams and rivers) and **still waters** (e.g. lakes and ponds) are not just significant structural elements of the landscape (including by virtue of their dynamics), but are also important reservoirs and conveyors of the substance and energy balance. Surface waters have an important substance exchange and transport function, and are also involved in the migration and gene exchange of aquatic and terrestrial organisms. In addition they play a prominent part in site repopulation and succession.

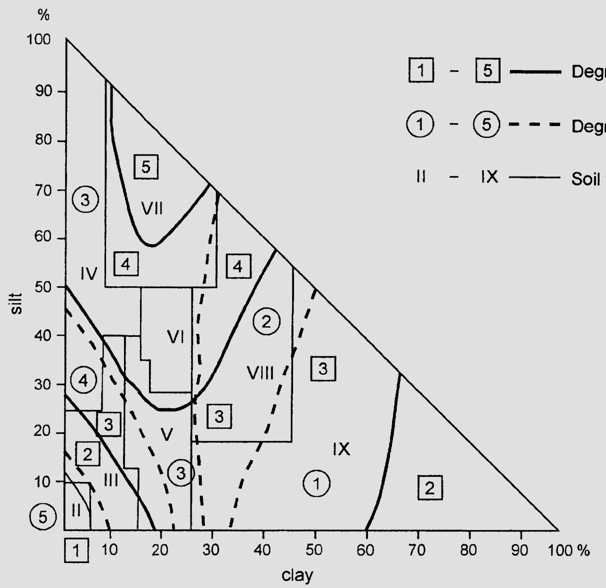

Figure 3.2-7: Soil water triangle (after Zepp 1988)

All in all, bodies of water have the following **functions**: drainage, water retention, substance transport and storage (including fixing), energy storage and flow, self-cleaning, providing habitats and contributing to evening out climatic differences (Figure 3.2-8). Furthermore, water bodies have an aesthetic, ethical and social function since they contribute to the beauty and diversity of the landscape, are involved in education and training, and are used for recreation (especially sports) and social activities among humans. We should also mention the importance of bodies of water for the energy and the food sector. As relatively closed systems, still waters became the first subjects of ecosystem research (Thiemann 1920, 1925, 1956).

Compiling a **typology of running waters** is still tricky. Initial attempts at spatial analysis on the topological scale involve defining the typical sections of running waters in terms of the main features of valley and water-body morphology, bed substrates, the oxygen level, the hydrochemical and hydraulic conditions, and biotope development (Mehl and Thiele 1998).

The **landscape ecological analysis** and assessment of a body of water starts in the catchment and source area, and examines the entire course with all its influents. The geological subterranean area through which the source water flows primarily determines the water chemism. The chemism is also influenced by inputs from the surface, especially land use in the catchment area. Moreover, airborne inputs and evaporation affect the substances and their concentrations in a body of water.

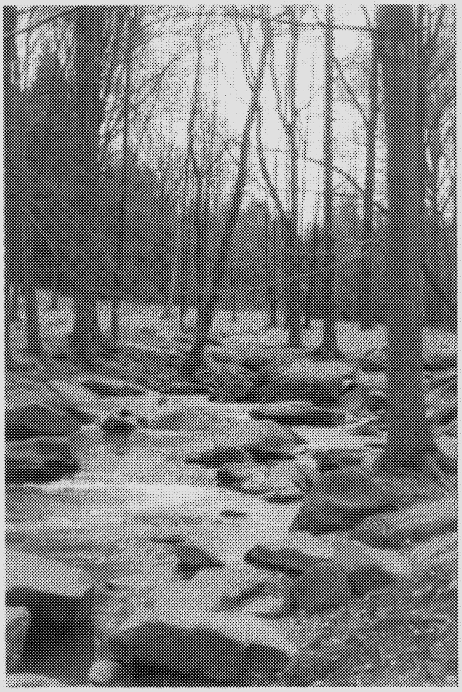

Figure 3.2-8: Running waters meet various functions in the landscape, e.g. matter transport and exchange, habitat, beauty and diversity of the scenery: The rivulet Spree in the Upper Lusatian low mountains (Saxony, Germany) (Photo: O. Bastian 1998)

In terms of mineral composition, a distinction is drawn between "soft" water low in Ca and Mg ions and "hard" water rich in these elements. Moreover, describing water as acid or alkali and fresh or salty is also common practice. Acid lakes and rivers may be mineral acidic (caused by pyrite weathering or flue gas) or humic acidic (moor waters). In terms of color, water is divided into clear and brown, while cloudy water containing minerals (e.g. glacier run-off) also occurs.

The landscape ecological analysis of a body of water entails a thorough knowledge of its biotic and **abiotic components**, its changing structures, functions and activity rates in the system. Particular importance is attached to recording the structural characteristics in various sections of the water, the average quantities of water and the expected water-level fluctuations. Other parameters include the changing flow speeds, water temperatures and oxygen levels. Moreover, the morphometric characteristics of the bed, its cross-sections and longitudinal profile, the composition and texture of the bed, the shape of the banks and floodplains, and especially in small valleys the entire valley profile all need to be gauged. The type of sediment transport is also important in sections where erosion or accumulation prevails. In particular gravel banks and steep banks form important habitats. A comprehensive list of morphometric, hydraulic, thermal and chemical parameters as well as parameters referring to the catchment area for the characterization of bodies of water and their pollution as well as to estimate the water quality is contained in Bastian and Schreiber (1999). Haase et al. (1986) compiled a series of ecologically relevant morphological and pedological classification patterns for bodies of water in floodplains, various forms of valleys and lowlands.

Biological techniques for determining water quality include indices of species diversity, species deficits and the degree of saltiness (halobiontic index). Compared with chemical water analysis, biological techniques have the advantage that by being an integrated scale they express not merely the momentary state of a body of water or certain parameters, but rather the worst state persisting over a certain protracted period.

The **saprobity index** is probably the best-known water quality parameter. It summarises the number of species encountered in bodies of water and their indicator value within a characteristic value indicating the water quality. This enables particular changes to the water quality in the various sections of a river or stream to be depicted. Especially in connection with measurements of organic pollution and oxygen content, it enables classification with information on other make-up criteria. Individual species of organisms also have a diagnostic value depending on their presence or absence.

However, the aquatic biocoenosis and the landscape ecology value of a body of water are also determined by **other factors**. These include the make-up of the floodplain, the rock composition in the catchment area, the bed substrate, the flow conditions and sediment movement, the repopulation possibility (e.g. the lack of ascent barriers, the formation of sediment hollows providing refuge during flooding), hydrological parameters (above all flash flooding and low water), the water temperature, chemism (pH, pollution by heavy metals, nitrate, phosphate etc.) and other impurities from human activity, e.g. pesticides. A similar albeit coarser division by ecologically relevant sections of water bodies can be carried out on the basis of its fish population.

3.2.5 Climate

For professional urban planning and agricultural land use assessment, a detailed analysis and large-scale mapping (1:5,000 – 1:25,000) of the **climatic situation** is an indispensable prerequisite. Of special interest are the bioclimatic elements cold air, frost, fog, smog and air quality, and solar radiation. The local dynamics and distribution of these elements cannot be derived and extrapolated from data of a near-by weather station because of their great variation in non-uniform terrain.

Accumulating in valley bases and terrain depressions, **cold air** can cause frequent radiation fog and black ice which impairs road traffic. In cold air pools late frosts can occur in the spring and early frosts in the fall which damage frost-sensitive crops and reduce the growing season. On the other hand, cold airflows can bring relief to the residents of a conurbation in hot summer nights. Therefore, it is important to take into account the distribution pattern, frequency of occurrence, and dynamics of cold airflows within a planning area and its vicinity.

The airflow over non-uniform terrain is not easy to generalize. Small topographic variations in relief and surface properties (slope inclination, roughness of terrain, vegetation cover, etc.) modify the cold airflow. Every hill, depression, and even small terrain obstacles like trees, rocks, and buildings create a perturbation in the pattern of flow. This unique mesoclimate of a landscape cannot be depicted and mapped by analyzing data from adjacent weather stations only. If available, thermal images from satellites which show the surface temperatures of the investigation area should be analyzed and evaluated (Gossmann 1984). To get detailed mesoclimatic information on the **flow and distribution pattern of cold air** in the planning area, it is indispensable to carry out temperature and humidity recordings along traverse routes by car or on foot, preferably during autochthonous weather situations where nocturnal eradiation and temperature decrease are at a maximum. A large-scale topographical map, an altitude meter, a digital thermometer and hygrometer with external sensors, a data logger or a precision clock and a tape recorder are needed. The planned recording route, traversing the investigation area several times, with distinct measuring locations which can be easily identified at night are plotted on the map (Glawion 1993, Figure 3.2-9).

Phenological observations can supplement temperature recording traverses. The first seasonal occurrence of characteristic phenophases (e.g. budding, flowering, fruit ripening, unfolding of the leaves) of selected plant species are registered by date. While this method is more suitable for meso- to small-scale mapping of a region, another approach to phenological analysis is the concept of a growth-climate map (Schreiber 1983). It is designed to yield results within one or two vegetation periods for detailed, large-scale planning. Along a transect route from the lowest to the highest elevations of a study area the different phenophases of selected plant species (widely distributed trees, shrubs, and herbs with conspicuous development of shoots) are registered within one day. Phenologically homogeneous terrain sections where nearly all the individuals of a species exhibit the same phenophase are classified into phenological stages and are considered to possess a uniform growth-climate.

The distribution pattern of cold air can also be mapped phenologically. After a late frost night in the early growing season, the percentage of frost-damaged buds or flowers of selected plant species (usually orchard trees) is registered. The resulting map of different classes of frost-damage gives a good overview of the areas of cold air pools and their vertical extent up-slope or up-valley. Such frost "pockets" should be avoided when planting frost-susceptible plants or trees.

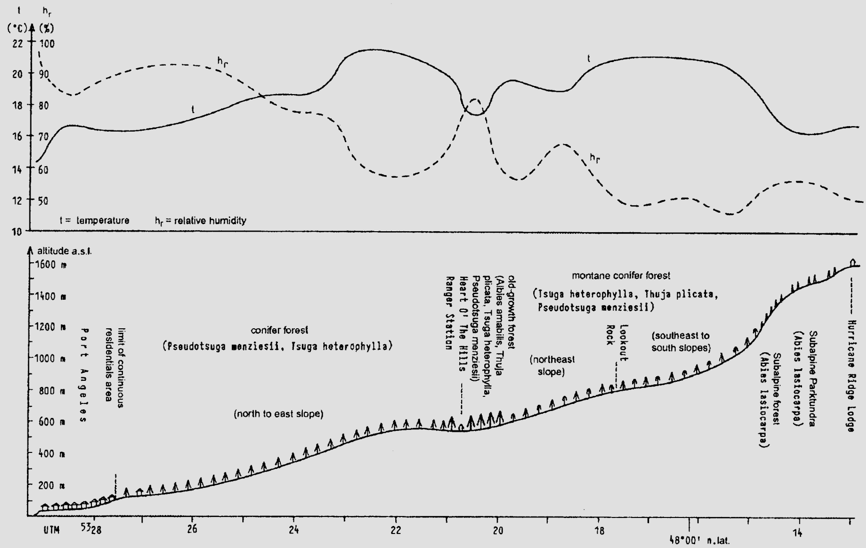

Figure 3.2-9: Transect of the northeastern Olympic Mountains from Port Angeles (at sea level) to Hurricane Ridge Lodge (elevation 1600m) with vegetation altitude zones. Corresponding curves of temperature and relative humidity recorded during a traverse on Aug. 8, 1986, 23:30 PST reference time. Intense nocturnal eradiation resulted in the production of cold air on the ground which drained down slope and settled to these lowest-lying portions of the city of Port Angeles. Above the coastline, air temperature rose with increasing altitude along the traverse route up the northern slopes of the Olympic Mountains (valley inversion) until it reached its maxima at an elevation of 400-600m and 800-1200m (thermal belts). At greater altitudes, the normal adiabatic decrease of temperature with height prevailed so that the temperatures at sea level and at 1500m elevation coincide (modified from Glawion 1993)

The amount of incoming **solar radiation**, differentiated into diffuse and direct-beam short-wave radiation, depends on the geographical latitude, the season, slope inclination and exposure, possible shading from surrounding terrain obstacles (mountains, trees, buildings, etc.), and the transparency of the atmosphere (e.g. concentration of aerosols around urban or industrial agglomerations) of a specific site. With these factors determined, the potential daily, monthly or annual duration and intensity of sunshine (direct-beam radiation) of that locality can be found in meteorological tables (Alexander et al. 1999, Morgen 1957). Maps depicting classes of solar radiation (from very high radiation gain to very high radiation deficit) are valuable for assessing the suitability of sites for agriculture, especially for growing thermophilic crops (e.g. vineyards, orchards), and for urban development.

Although **air quality** is an important factor in urban planning, in most cases it is not analyzed chemically but only assessed indirectly by interpreting climatic and topographic data. The pattern of cold airflows and the distribution and frequency of cold air pools with temperature inversion and radiation fog yield important information for aspects of urban ecological evaluation. In combination with data on local topography, building structures, land uses and industrial emissions, an ecoclimatic planning map can be compiled (Stock 1992).

Bioindication is another widely used method to assess the differences in air quality within an investigation area. Bioindicators give a more life-related expression of air pollution and its possible biological effects on plants, animals, and humans than chemical analyses (see Chapter 3.3). Due to their sensitivity to harmful airborne chemicals, the most widely used bioindicators are epiphytical lichen. Under standardized conditions, identical lichen are distributed evenly within the study area and exposed to the air. After a given time period, the lichen are classified according to the severity of the visual change of their physiognomy (e.g. partial dying off) resulting in a map of zones of different lichen damage (Steubing and Jäger 1982).

Due to the widely-spaced network of **permanent weather stations**, most climatic elements can only be depicted in small- to meso-scale maps by means of extrapolation. They are hardly suitable for detailed information in local planning (Schreiber 1994).

Air temperature is read in a standardized weather hut at 2 m height. Extremes or means of temperature can be calculated for selected time periods. If non-permanent temperature stations are set up for only a few years in a specific planning area, their data have to be linked to the long-term recording periods (usually 30 years) of near-by permanent stations. Additional information on spatial temperature distribution can be derived from phenological observations and from thermal infrared air or satellite images which show surface temperatures (Gossmann 1984).

Precipitation is measured in a precipitation collector (according to Hellmann) at 1m above ground. These stations are much more closely spaced than the weather stations. However, there is significant spatial and temporal variability of precipitation in non-uniform terrain so that the extrapolation of precipitation data is problematic. Not only slight orographic differences, but also land-use patterns (urban areas, forests) can influence precipitation.

Information on average and maximum **wind velocity** and the prevailing wind direction in the atmospheric surface layer for different weather situations is important for aspects of rural and urban planning (e.g. assessment of air quality, wind chill, ventilation in planned housing developments). In contrast to some other climatic elements, wind data from near-by weather stations cannot be extrapolated to be used in large-scale maps. A method of bioindication is sometimes used: classifying and mapping the crown deformation of trees in open, wind-exposed terrain to get detailed information on the prevailing direction and average velocity of the wind near the ground. If the precise wind field is required, e.g. to predict the wind effect around a planned large urban structure, it is best to model the situation by building a scale model and subjecting it to flow simulations in a wind tunnel (Oke 1987).

3.2.6 Bios

The term "bios" includes all biotic factors of an ecosystem, i.e. plant and animal communities. In this chapter it is used in a broader sense to describe the analysis of flora, vegetation, fauna, biotopes, and land use.

Three main approaches to **analyzing flora and vegetation** for site diagnosis, landscape characterization and landscape classification are outlined in Figure 3.2-10. These methods are most widely used in Central European landscape ecology and biogeography. While the physiognomic-ecological approach is more useful for meso- to small-scale classification (1:50,000 – 1:1,000,000), the floristic-ecological and the floristic-sociological method are more suitable for large-scale characterization and delimitation of ecotopes (1:5,000-1:25,000). The term "ecotope" in landscape ecology is defined as a spatial unit of landscape ecological relevance with homogeneous abiotic and biotic environmental properties (see Chapter 2.2), while in the biological sciences and in synecology it is synonymous with the term "biotope" as living space of a biocoenosis with homogeneous site properties.

The **physiognomic-ecological approach** is based on life-forms of plants which result from adaptations to particular environmental conditions. Numerous botanists, plant ecologists, and biogeographers have attempted to classify the various life-forms by correlating them to specific ecological factors. One of the most widely used classification systems with world-wide recognition originates from Raunkiaer (1934) who differentiated life-forms by their adaptations to survival of the cold or dry season. The most important differentiating feature is the position of the buds with respect to snow cover. E.g., phanerophytes (trees and tall shrubs) have their regenerative organs well above the snow cover, while chamaephytes (dwarf shrubs etc.) have theirs protected under a continuous winter snow cover. Another well-known life-form classification is based on the adaptation of plant organs to water availability (Schimper 1898). He differentiated between xeromorphic, mesomorphic, and hygromorphic terrestrial plants as well as hydromorphic and helomorphic aquatic plants. In a more comprehensive classification, Schmithüsen (1968) used morphological and physiological features of environmental adaption relevant to landscape physiognomy and ecology to divide plants into 30 life-form classes. These serve as elements for **plant formations** (Grisebach 1838) which are the basic units of physiognomic-ecological vegetation typology (Figure 3.2-10).

If complete inventories of plant species are available, site properties of different stands of plants can be compared by composing and evaluating their **life-form spectra**. The percentage of each life-form (e.g. after Raunkiaer 1934) within the total amount of species of a stand can be calculated qualitatively (by number of species only) or quantitatively (by abundance and dominance of each species). Comparative analyses of life-form spectra depict mostly differences in climatic features (e.g. seasonal duration, reliability and height of snow cover, occurrence of frost, seasonal distribution of precipitation). Figure 3.2-11 illustrates the drastic altitudinal change of life-form spectra on south-facing mountain slopes in Iceland (Glawion 1985).

Living in their natural environment, under natural competition for space, light, water, nutrients etc., plants and plant communities reflect the environmental properties of their sites. However, only very experienced vegetation scientists and plant ecologists can attempt to attribute characteristic **ecological indicator values** to each individual plant species of an entire floristic region.

The geobotanist Ellenberg (1992), having studied the plant communities of Central Europe for more than 40 years, published an inventory of 2942 vascular plant species of Central Europe with their assigned indicator values for light, temperature, continentality, soil moisture, soil acidity, and nitrogen supply (see Chapter 3.3). For these six key site factors, the ecological affinity of each plant species in its natural environment is evaluated along a gradient from 1 (= least extent) to 9 (= greatest extent of a given factor). All plant species with a similar combination of ecological indicator values are grouped together. These **ecological groups** are named after one of their characteristic species (e.g. *Carex humilis*-group of dry, shallow, basic soils).

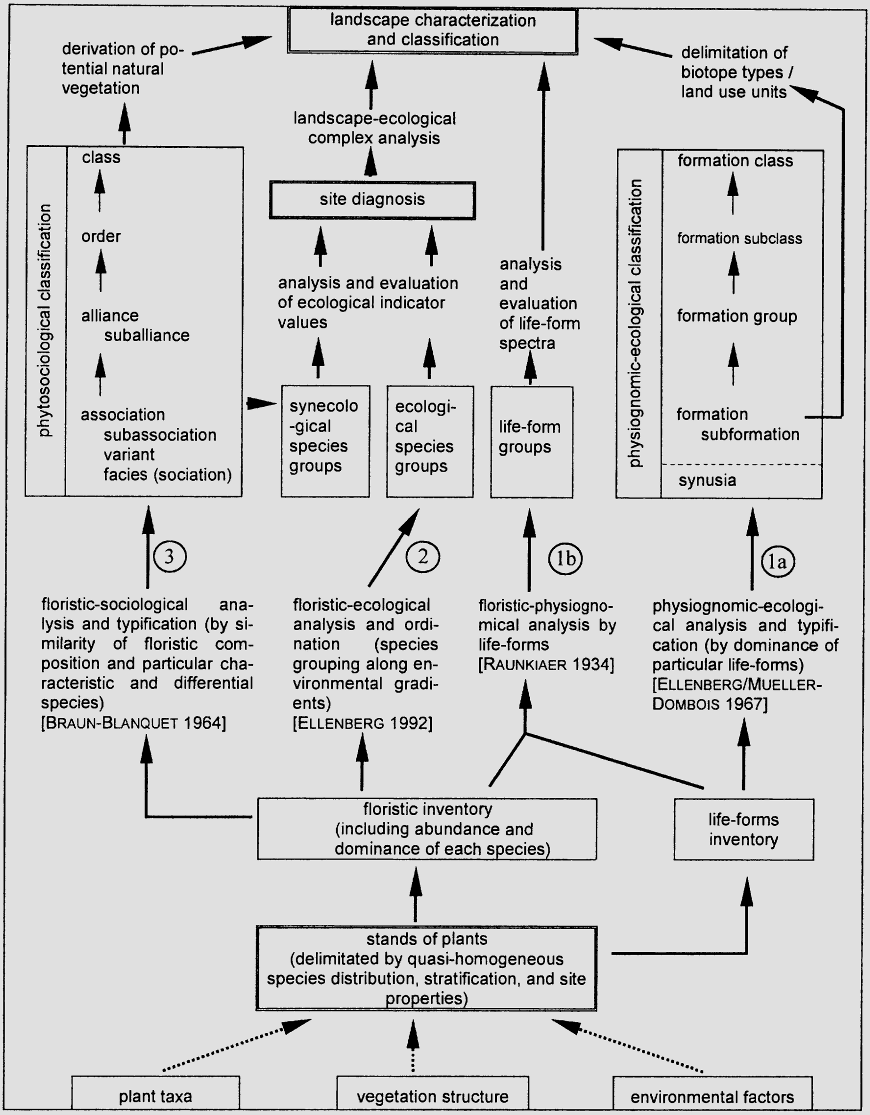

Figure 3.2-10: Three approaches to analyzing flora and vegetation for site diagnosis and landscape classification: 1a and 1b: physiognomic approaches, 2: floristic-ecological approach, 3: floristic-sociological approach

For site diagnosis, the ecological indicator values of all plant species in a given stand can be averaged for each key site factor (**floristic-ecological approach**). Since the average values are based on ordinal numbers, they cannot be interpreted on an absolute scale (e.g., the mean value of 8.4 for the light factor does not indicate that the light supply of this site is twice as high as the lighting situation in another stand with the average value of 4.2).

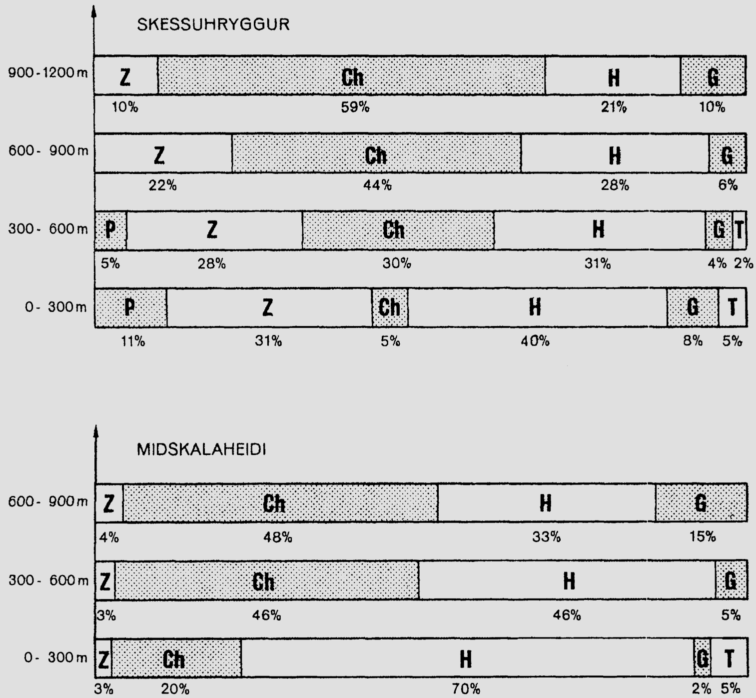

Figure 3.2-11: Life-form spectra of altitude zones on a mountain slope with southern exposure in northern Iceland (Skessuhryggur) and in southern Iceland (Midskalaheidi). P = phanerophytes; Ch = chamaephytes (without dwarf shrubs); Z = dwarf shrubs; H = hemicryptophytes; G = geophytes; T = therophytes: On both mountains the percentage of chamaephytes including dwarf shrubs (Ch+Z) rises clearly from low to high elevations, while the numbers of hemicryptophytes (H) and therophytes (T) drop sharply. While this is due to an overall altitudinal gradient of snow cover duration in Iceland, the generally larger percentage of hemicryptophytes on all altitude levels of Midskalaheidi compared to Skessuhryggur is due to the milder winters in southern Iceland where snow cover is unreliable. (adapted from Glawion 1985)

The floristic-ecological approach to site diagnosis, using Ellenberg's ecological indicator values, is limited to Central Europe. However, in other floristic regions of the world, there have been similar, though less comprehensive, studies. Most of them have the purpose to assess the productivity of a site for timber or crop growing (e.g. Daubenmire 1976). The floristic-ecological site evaluation is not limited to the above-mentioned six key factors. E.g., in nordic countries like Scandinavia and northern North America, the snow cover is a much more important factor than some soil factors which are subdued by a commonly thick layer of raw humus in boreal climates. The ecogram in Figure 3.2-12 depicts chionophobic (snow-avoiding) and chionophilous (snow-dependent) ecological species groups in Iceland, aligned along a gradient of snow cover duration. These species groups have been identified by thorough investigation of the ecological affinities of plants in Iceland, and are used as bioindicators for site evaluation and landscape assessment (Glawion 1985, 1989).

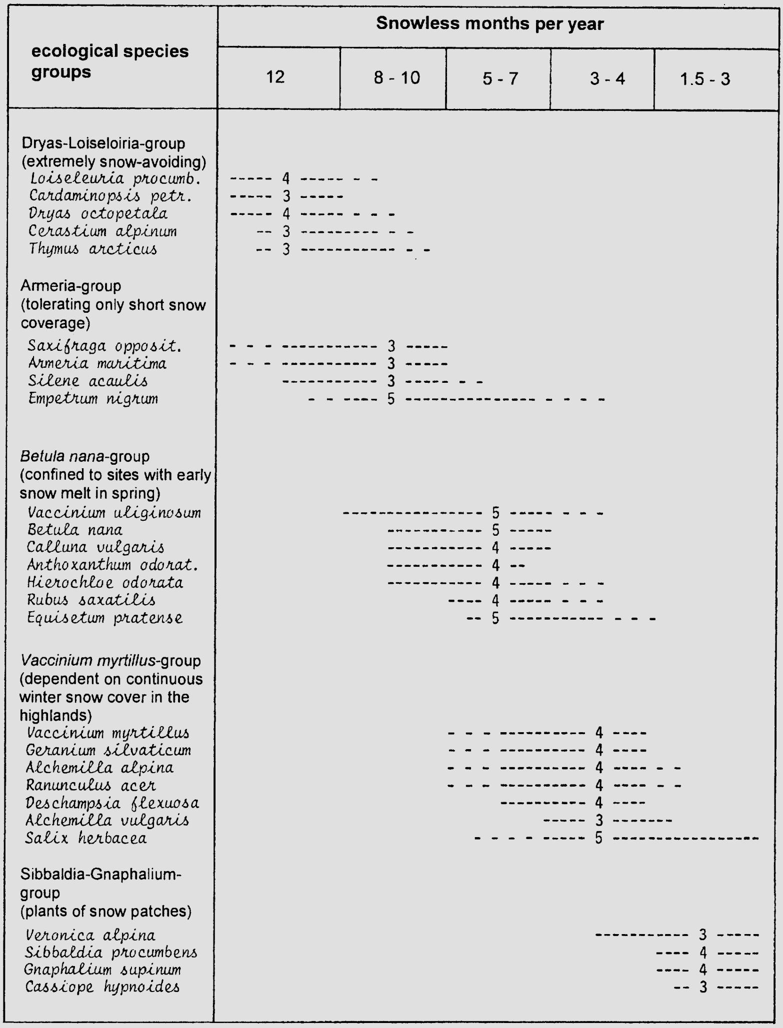

Figure 3.2-12: Ecogram depicting ecological groups as bioindicators for snow cover duration in Iceland. The broken line next to the name of a species indicates its ecological optimum range, the number indicates its maximum dominance within this range (adapted from Glawion 1985)

The **floristic-sociological approach** aims at typifying and classifying plant communities on a floristic base (Figure 3.2-10). First, stands of plants in the investigation area are selected and delimitated by quasi-homogeneous species distribution, stratification, and site properties. Second, their complete floristic inventory is taken. Not only all the species are listed, but also their **abundance** (number of individuals per species) and/or their **dominance** (percent coverage of all individuals of each species) are estimated. By comparing the similarity of species composition of the analyzed plant stands, plant community types are formed. Finally, referring to particular characteristic and differential species, the community types are integrated into the hierarchial phytosociological classification system. While **characteristic species** define the various plant associations, alliances, orders, and classes of the system, **differential species** subdivide associations by site differences within their areas into subassociations, variants, and sociations. For details on the methods of floristic-sociological analysis, typification and classification, see Braun-Blanquet (1964), Knapp (1971), Kreeb (1983), and Klink (1996). Although the classification system of Braun-Blanquet, due to its statistic-structural approach, is not directly applicable for landscape ecological purposes, the lower units of the hierarchial system which are defined by differential species can be used for site diagnosis.

A group of differential species with similar environmental requirements and belonging to the same vegetation unit (e.g. a specific sub-association) are called sociologic-ecological or **synecological groups** (Scamoni and Passarge 1959, Schlüter 1957). Their advantage to the previously described sociological or ecological groups is that their species combination can be analyzed and evaluated for their floristic-sociological characterization as well as for the assessment of their site conditions.The environmental indicator values of synecological species groups and vegetation units can be depicted by **ecograms**. It is not feasible to arrange them along single-factor gradients since in their natural environment plants respond to the variation of a complex of interrelated factors by a change of species combination or dominance (Figure 3.2-13).

Within the densely populated European continent where human influence on the vegetation started several thousand years ago, the natural vegetation has almost been replaced everywhere with human-made plant communities (see Chapter 4.1). Since it is very problematic to correlate them with natural environmental factors, the potential natural vegetation is often used to assess the present-day ecological growth potential of an area. The **potential natural vegetation** is a state of the vegetation which would theoretically be existent (as today's climax communities) on all present-day sites if human influence had stopped (Tüxen 1956). It can be derived from still-existing remnants of vegetation close to nature and from site analysis.

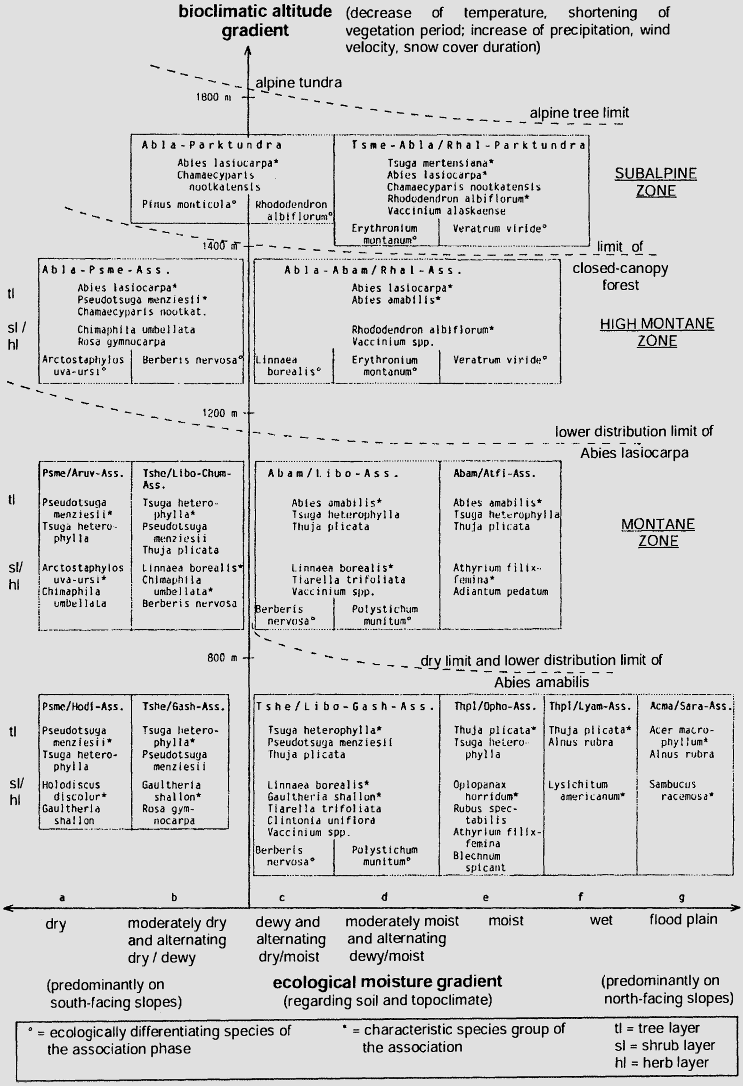

Figure 3.2-13: Forest associations of the northeastern part of the Olympic Mountains (Washington State, USA), arranged along a complex ecological moisture gradient (horizontal gradient) and a complex bioclimatic altitude gradient. The moisture gradient takes account of the water supply by surface and ground water, soil moisture, and topoclimate (air humidity), and the vertical gradient comprises the altitudinal decrease of temperature and shortening of vegetation period, and increase of precipitation, length of snow cover, and wind velocity. Associations in this figure are defined as phytosociological units of the potential natural vegetation (climax communities), characterized by the same dominant species in the tree layer and in the understory. Ecologically differentiating species, usually confined to the herbal layer, subdivide associations into phases which allow a more detailed site analysis (adapted from Glawion 1993)

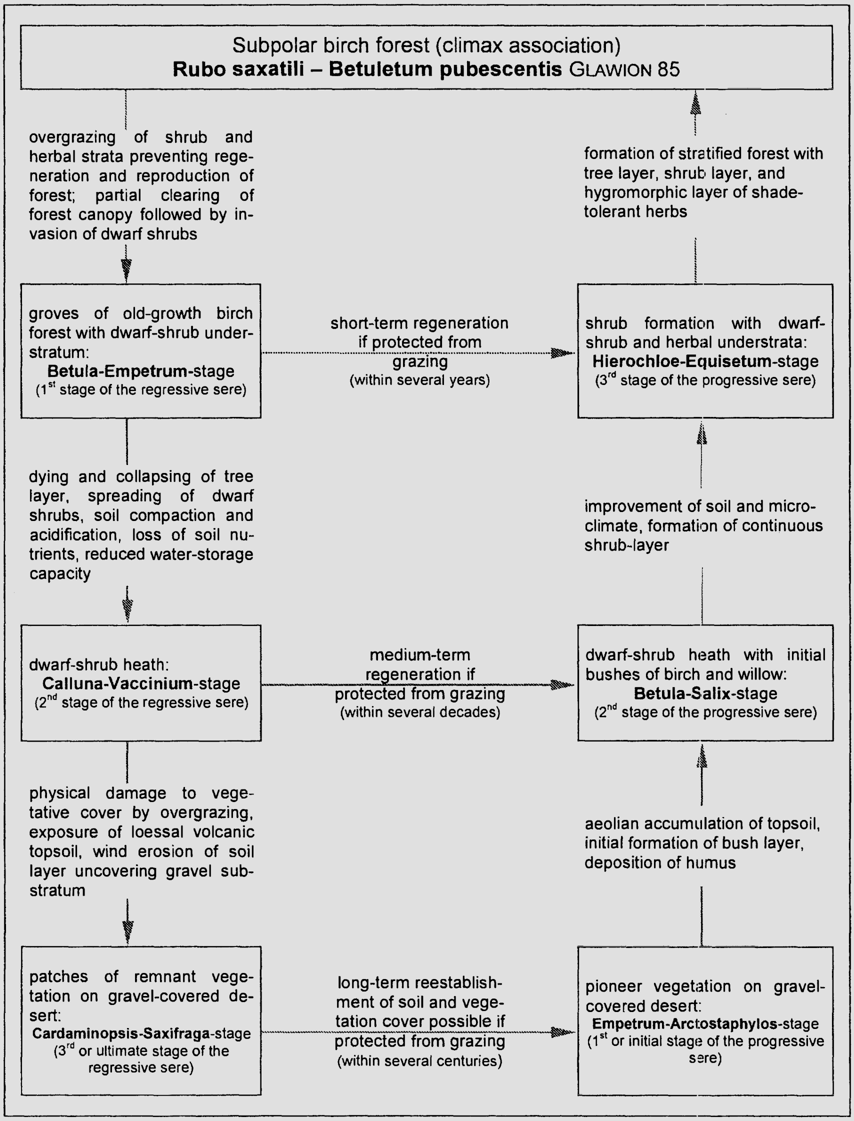

Figure 3.2-14: Climax complex model of the subpolar birch forest formation in Iceland with Rubo saxatili – Betuletum pubescentis as climax association, and its regressive and progressive succession seres) (modified from Glawion 1986a)

Figure 3.2-14 depicts a climax complex model of the subpolar birch forest association *Rubo saxatili-Betuletum pubescentis*. As the potential natural vegetation of Icelandic lowlands it is linked to **progressive and regressive succession seres** of secondary plant communities. The climax complex model is used for landscape protection, control of soil erosion and deforestation, and rehabilitation of degraded and eroded grazing lands in Iceland. Once a distinct vegetation succession stage of a degraded site has been identified in the model by comparing its species combination, suitable rehabilitation steps can be implemented (Glawion 1985, 1986, 1987).

The habitat requirements of the **fauna** and the ecological indicator values of individual animal species have not yet been investigated as thoroughly as of the flora and vegetation. This is partly due to the high mobility, the great number of species, and the problems to delimitate a faunistic habitat which makes it more difficult to consider animals in landscape analysis and landscape assessment. Nevertheless the fauna plays an important role in biocoenoses and ecosystems (Figure 3.2-15).

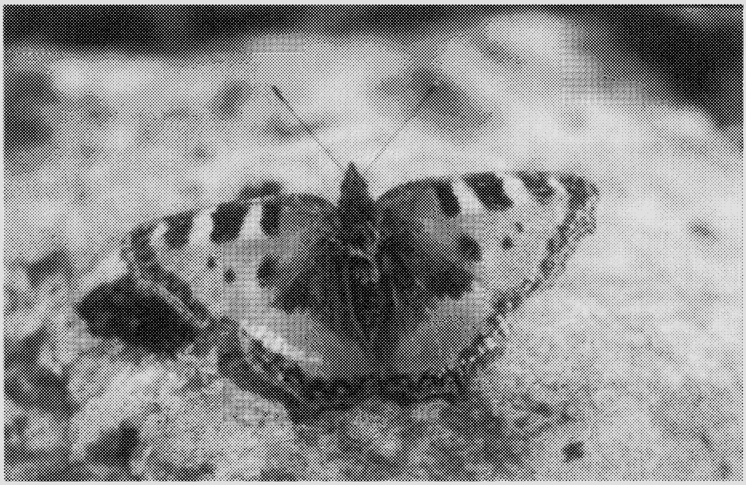

Figure 3.2-15: Thanks to their conspicuousness, butterflies (e.g. Nymphalis polychloros) belong to those insect groups which are especially suitable as bioindicators (Photo: O. Bastian 1985)

To cope with the problems, representative animal species (or species groups) are selected which fulfill the following requirements (Bastian 1994, Zucchi 1990):

- sufficient distribution and frequency in the study area,
- well-known in their taxonomy, biology and ecology,
- reproducable methods of their sampling and recording,
- representing the entire biocoenosis as "key indicator species",
- representing different levels of the food chain and various types of niches, and
- preferably including endangered species from the standpoint of nature conservation.

For analyzing selected biotopes the following species groups are best suited as bioindicators: small mammals, birds, reptiles, amphibia (for aquatic biotopes), dragonflies, grasshoppers (mainly for dryland biotopes), bees, butterflies, soil-inhabiting and wood-inhabiting beetles, and snails (Plachter 1989).

The **field methods** of sampling animals vary depending on the selected species group. A quantitative analysis of the population density can be achieved by observation and visual counting of individuals and their breeding places (burrows, nests), by catching and trapping (amphibia, reptiles, insects), by random sample mapping and line taxation (Coch 1999, Riecken 1992). The inventory of species, their abundance, and their ecological requirements are analyzed and evaluated to characterize the biocoenosis and the biotope for landscape assessment and landscape planning.

In most investigations and assessments for nature preservation, only landscape units which are worth protecting are called biotopes. Identical or similar biotopes comprise a **biotope type**. A characteristic pattern of different biotopes in a confined space is called a **biotope complex**. Mainly in urban areas where it is difficult to identify individual biotopes, biotope complexes have been defined. A widely used inventory of biotope types in Germany has been published by Pott (1996).

In **biotope mapping**, the term biotope is used in a slightly different sense for practical purposes: "A biotope is a landscape unit which is delimitated from adjacent landscapes by vegetation typological or landscape ecological features" (Landesanstalt für Umweltschutz 2001). Hence, for identification and characterization of biotopes, keys for biotope type mapping can comprise plant associations, plant formations, life forms, and land use types, morphological and aquatic features. Some biotope types cannot be defined by plant associations (e.g. caves are defined as a morphological feature and crop fields as a land use unit). Vegetation with a high human impact is better differentiated by its physiognomic than by its floristic composition. Only near-natural remnants of vegetation can easily be identified as plant associations. Haeupler and Muer (1999) have developed a key for identifying the biotope types of Germany, based partly on the syntaxonomical systematics in Pott (1995). To speed up biotope mapping, simplified keys are often used as a combination of land use units and vegetation structure types. These can be quickly identified in aerial photographs, and they can be correlated with specific groups of animal species which are confined to a characteristic structural type of vegetation (e.g. coverage and height of individual strata) or vegetation pattern (e.g. combination of hedges, groves, edges of forests and waters). Correlating the known ecological requirements of selected animal species with the vegetation structure types enables the landscape planner to assess the biotope suitability of his study area for these animals as their **habitat**.

The numerous methods of biotope mapping, including urban biotope mapping, can be assigned to one of three principal categories:

- **selective biotope mapping** only considers biotopes worth protecting. With this method, large areas are mapped to identify and secure valuable biotopes for nature conservation,
- **comprehensive biotope mapping** includes all biotopes (rural, urban, forest, etc.) of the study area. It is used for detailed landscape analysis and planning purposes, and
- **representative biotope mapping** combines both methods mentioned above. For all land use types of the study area representative test areas are investigated and the results are applied to all the remaining areas with similar land use structure.

3.3 The indicator principle

3.3.1 Definitions and demands

It is very difficult to throw light on the complicated relationships within ecosystems and landscapes with a justifiable expense and to look at EVERY interaction and connection. Therefore, suitable parameters are necessary, so-called indicators, in being able to characterize the whole system in an adequate manner. In natural sciences an **indicator** signifies a plant or an animal, a substance or, in general, an object verifying a variable that cannot be measured directly. So the appearance or disappearance of specific lichens is an accepted sign for air quality. In landscape ecology and landscape planning this term is used in a more complex manner, especially with respect to target systems. Natural sciences need descriptive indicators whereas planning needs normative indicators in addition to the descriptive ones.

Indicators can be grasped rather easily, and they can be used to explain the particular problem favorably. In contrast to indicators, **parameters** can be measured immediately, and they enable direct conclusions.

Insights into complex systems can only be gained for selected components. Because it is impossible to register all interactions and response coherences within a specific system selected indicators will be used that are representative to characterize certain states or operation modes of the whole system. Indicators provide signs for a putative state or operation mode of a considered system (saproby for water quality or lichens for air quality – as mentioned above).

Indicators do not serve for the analysis, acquisition and assessment only but they can also be used for their simplification by reducing the manifold system's mechanisms to the significant correlations. Therefore, discrimination into three classes of indicators following the pressure-state-response-approach has been enforced (CSD 1997, OECD 1994):

- **Pressure indicators** will be used for the analysis of the factors and resulting effects as well as the sensitivity to certain effects of measurements (e.g. input of phosphorus into waters).
- **State indicators** enable the indication of certain conditions or developments, such as phosphorus concentration in waters or natural site conditions by the use of indicator plants in agriculture and forestry (see Chapter 3.3.4), but also human influences on the environment by changed features of biological objects and systems compared with defined reference conditions.
- **Response indicators** conduce the development, selection and control of political measurements (e.g. phosphorus concentration in the outlet of a sewage treatment/purification plant).

Unspecific indicators react to different factors in the same way, whereas the reaction of **specific indicators** can be related to one defined environmental factor. If single attributes represent the indication directly, we have to do with so-called single, analytical or **primary indicators**. If two or more influencing factors have to be considered to characterize a phenomenon, single attributes respectively indicators must be combined to derived, compound or **aggregated indicators**. The aggregation is carried out step by step from the lower to the higher level (Bastian 1992, 1999a).

The process of indication should be understandable, and more or less objective. In addition, indicators should also meet the following **requirements** (from Müller 1996, modified):

- general possibility to collect the information,
- validity, sensitivity,
- methodical intelligibility, representativeness, repeatability,
- spatial and temporal comparability, integrability, and
- unambiguous relation of the effect.

A general principle of indication is KIS = "Keep it simple", to avoid overtaxing people and to improve political acceptance, especially in the field of nature and environment.

Indicators provide, however, only indices for the description or assessment of a state or a development. This is a remarkable **limitation**. In addition, uncertainties, limitation to details of the problem, subjective influences and normative assumptions are characteristic features of indicators. So they have to be interpreted carefully and with respect to the specific question. For instance, the air quality index based on lichens does not necessarily provide information on the actual air pollution. Lichens are sensitive to acids. They are an appropriate medium assessing the concentration of SO_2 and NO_x in the air. In contrast they do not give much information concerning the pollution by soot or hydrocarbons (Kühling et al. 1997). The saproby index (see Chapter 3.2.4) describes water quality, but does not give much information about the state of the riverbed, river profile or buffer strips. In an extreme case, this selective approach could lead to false conclusions.

Also planning practice is confronted with the problem of looking for indicators. Often they will be selected from each planner or surveyor individually and are therefore different from investigation to investigation. This can lead to problems in comparing and understanding different case studies.

All trials to develop indicator sets failed up to now due to the complex task. What we need is a system of indicators (SRU 1994) that is able to represent the difference between an indicator (actual matter concentration, matter input, and structural interventions) and a threshold value (critical matter concentration, critical input rates and critical structural interventions). But this is exactly what environmental planning needs to get out of the surveyor concerning the indicator sets. Up to now, not only are indicators missing but also the according threshold values conducing as assessment rule. We have to doubt whether there will be an area covering approach with indicators and threshold values. There is an overwhelming investigation effort only for regionalization exceeding the capacities of actual landscape planning by far. Besides structural indicators belonging to the standard program of qualified landscape planning, concentrations and input rates also had to be detected and assessed for regions. Until now, this is realized only for the management planning of selected water courses being important or problematically.

Because of the complexity of landscape structures and processes, a single indicator can contribute to the characterization of several landscape functions equally. This fact should be considered for the **choice of indicators** in order to achieve good results with low expenses of time and costs. The indicator principle represents a compromise between the desired objectivity and complexity of the information, and the necessary practicability of the approach. With the help of an optimal set of problem-related indicators, a better integration of ecological basic knowledge into practical planning processes is possible.

The intelligent choice of indicators influences the quality of results essentially. Drastic restrictions result from available information in the test area. A critical assessment of all applied indicators is always necessary. The step from a simplification to a misinterpretation is small if complex environmental issues are simplified and reduced to only a few indicators, and if the result achieved loses any sensible relation to the ecological reality. The decision as to which attributes and indicators are especially suitable to solve a certain task, depends e.g. on the specific question, on the type, complexity and size of the object, and on the desired differentiation of the result.

Within a well-developed concept of landscape analysis and planning, such indicators should be applied as are significant and geared to the concrete aim, the size of the test area or the scale (planning level), and the specific landscape character. That is not easy at all, since e.g. in landscapes heavily influenced by man, especially in eutroph and "cleaned" landscapes indication is not easy because of the lack of indicator species. The insufficient knowledge of ecological effects and relationships leads to noticeable consequences, too. Admittedly, it is often possible to describe certain facts verbally, but not to quantify them. Consequently, the range of available information is heterogeneous and incomplete, it comprises "hard" as well as "soft" data, measured and estimated values, information from comparisons, primary and secondary data, and also information based on intuitive experiences. In some circumstances, the last can be more valuable than measured data, which are not always representative and valid, and their gathering expensive. The search for information should not be limited to quantitative data, since not all important information can be quantified. The ignorance of qualitative facts narrows the view on the reality unnecessarily (see Chapter 5.3.).

3.3.2 Bioindication

In the field of nature conservation and landscape management, structure and functions of nature and landscape can be characterized with the help of indicators. A special field concerns **bioindicators**: organisms whose life functions can be correlated with certain environmental factors so closely that they can be used as indicators for them (Ellenberg et al. 1991, Schubert 1991). This indication can be realized by presence or absence of certain species or by specific features such as life form and growth form (habit), life rhythm (phenology), abundance, species spectrum, but also by material peculiarities. Plants and animals make good indicators in landscape research, for example in assessing the quality of the air, water and soil, and in detecting pollution and landscape changes (Table 3.3-1, see Chapter 3.2.6). Bioindication, then, makes it possible to estimate the total impact of a variety of nonspecific harmful effects and illustrate it for larger areas (Figures 3.3-1 and 3.3-2).


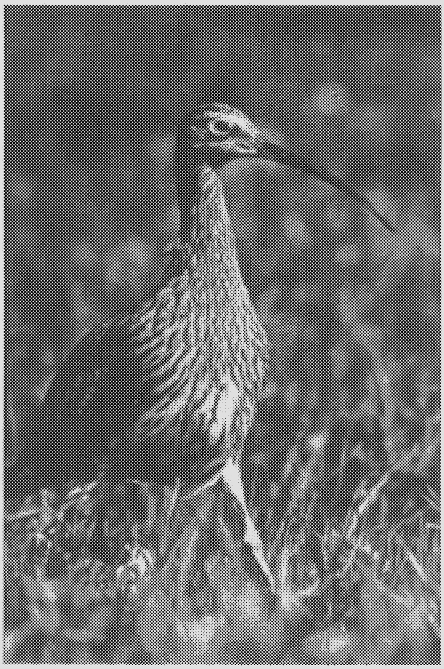

Figure 3.3-1 (left): Botrychium lunaria is a rare fern of acid rough meadows heavily threatened by intensive land use and nutrient accumulation (Photo: O. Bastian 1980)
Figure 3.3-2 (right): For breeding, the curlew (Numenius arquata) prefers wet extensively used grassland (Photo: reproduction)

The ecological behavior of a plant species in the landscape is not identical with its physiological optimum. The principle of relativity in ecology means that the ecological importance of one site factor for an organism (plant, animal, human being) does not depend only on its own extent (quantity) and development, but from the total ecological situation as well, i.e. from all other factors influencing this living being (Dahmen and Simon, 1997). Therefore, the validity of indicator values can be limited to certain (plant) communities or regions. Even within Central Europe, the ecological and sociological behavior of plants often varies between different landscapes leading to the necessity to specify the indicator values (Schubert 1991). Besides, the ecological inhomogeneity of many species should be considered: often numerous "ecotypes" can be distinguished. A further difficulty is the slow reaction of many species to habitat changes.

There are, however, a lot of **critical aspects** and limitations, especially caused by methodological problems and a lack of knowledge. Serious obstacles result from the mobility of animals, their ecological valence which is manifold and often unknown, the almost infinite number of species, a concealed existence which allows observation of many species for short periods only, and the high cost of study.

Table 3.3-1: Examples of bioindicators for environmental impacts and ecosystem changes

hierarchical level/ dimension	indication / indicandum	indicator
ecosystem / biocoenosis	- mechanical threats (trampling)	- vegetation changes (damages)
	- eutrophication of terrestrial ecosystems	- communities of plants (phytocoenoses) and mushrooms (mycocoenoses)
	- water eutrophication	- reet fringes
	- air pollution (emissions)	- forest structure, plant biomass, phytocoenoses
species, taxocoenosis, populations, individuals	- complex landscape changes	- changes of bird and smaller game animal populations
	- water eutrophication	- species spectrum of waterfowl and water plants
	- air pollution (emissions)	- occurrence of mushrooms, molluscs, arthropods, birds, small rodents, lichens, mosses and higher plants (floristic changes)
	- threats by biocides	- aquatic and terrestrial flora and fauna
	- heavy metals (e.g. Pb, Zn)	- distribution of plants adapted to heavy metals
	- salt	- distribution of halophytes (e.g. *Puccinellia distans*)
morphological, physiological, biochemical level	- air pollution (emissions)	- morphometric deviations (annual growth of shoots), life-span of coniferous needles, growth-ring chronology, necroses, chloroses, cell sap conductivity, contents of chlorophyll, protein, enzymes
	- threats by biocides	- soil respiration (by microorganisms)
	- heavy metals	- enzyme activities, contents of heavy metals (e.g. in game livers)

3.3.3 Diversity - always a criterion of landscape quality?

From the nature conservation point of view the number of species can be an important criterion for the value of an ecosystem or a protected area. In ecological textbooks, usually numerous **indices of ecological diversity** are described (related to the names of authors such as Margalef, Odum, Pielou, Shannon-Weaver, Simpson, Sørensen). Often, they suffer, however, from their restriction to single groups of organisms, difficulties in their calculation, the missing applicability to areas, i.e. the chorological dimension.

High species diversity within an ecosystem indicates a high complexity of ecological relations but it does not mean necessarily a high stability. For example, there are ecosystems poor in species but ecologically stable, e.g. *Phragmites*-reets, acidophilic beech forests, boreal coniferous forests. Several ecosystems are settled by a few but rare and highly endangered species and communities only, e.g. oligotrophic waters, high-moor bogs and heaths. The mere **number of species** alone does not characterize the quality and the value of an ecosystem! Always the relations to the type of ecosystem, the stage of development, the intensity of human interference, the site and the landscape type are evident.

The calculation of species densities (e.g. the number of breeding bird species in an area) can cause absurd results, because **species-area relations** are not linear, and different regions can be compared for certain purposes only. It is not justified to measure and to evaluate the species diversity (e.g. the number of breeding bird species) of a certain area on the basis of average expectations (see Table 3.3-2).

Table 3.3-2: Number of breeding bird species (S) in areas of different size (F) and resulting species densities (S/F) (from Scherner 1995). The species density seems to become higher with decreasing size of the test area. This is a wrong conclusion.

Area	F	S	S/F
state forest Neuhaus, department 91c	6.6 ha	11	127.9 km²
central Solling	20.0 km²	71	3.6 / km²
Solling*	427.0 km²	90	0.2 / km²
the whole without the Solling	149 millions km²	c. 8,600	0.00006 / km²

* a mountainous forest area in Lower Saxony (Germany)

3.4 Landscape ecological complex analysis

3.4.1 Basic principles

What is a landscape ecological complex analysis? The term **analysis** indicates that it is an investigation procedure. **Complex** points out that the investigation object is composed of several factors and functions – a system will be considered. And **landscape ecological** characterizes that a three-dimensional subset of the earth's surface will be investigated.

These general statements now have to be specified according to the research object as well as to the spatial dimension of investigation. Designed by Neef (1963) and Haase (1979) and further developed by Mosimann (1978, 1984b) as a method to analyze geographic-ecological complexes in elementary landscapes it can be considered as one of the main tools of the

European school of landscape ecology. It consists of two parts, the site analysis and the differential analysis. The **site analysis** follows the layered structure of an ecosystem and focuses on the vertical interaction between the layers or ecosystem compartments (according to the principle of correlation, see Chapter 2.4). A package of measuring and mapping methods has to be applied to quantify the interrelationships within and between the landscape's subsystems. The **differential analysis** examines each ecosystem compartment by itself in space in order to generate extent and borders of each landscape unit (according to the principle of areality, see Chapter 2.4). By combining the two parts, ecosystem processes and their spatial extent can be quantified on a small scale respectively in the topological dimension. The so realized integration of horizontal and vertical approaches to a landscape is a crucial point in holistic landscape ecology.

The problem of landscape ecological complex analysis is to register exactly – that means to measure – a lot of processes between physically different compartments (geoecological subsystems).

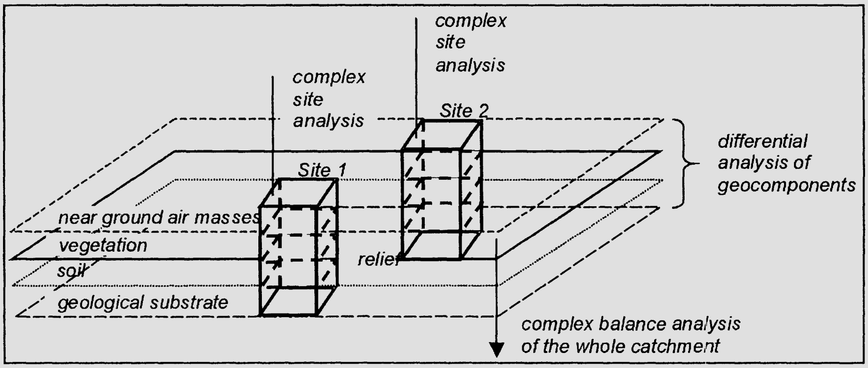

Figure 3.4-1: Site analysis, differential analysis and landscape ecological complex analysis (after Mosimann 1984b)

After Mosimann (1984b) the following basic methodological principles depicted in Figure 3.4-1 have to be considered:

1. **System approach**: Landscape is understood as a three-dimensional subset of the earth's surface as well as a fabric of storage, regulators and processes.
2. **Turnover and balance sheet analysis**: Investigations are focused on matter and water balances. Investigations of water turnover and water balance are the prerequisite to understand and quantify matter turnover and matter balance.

3. **Integration of horizontal as well as vertical examinations**: The space-related approach integrates horizontal as well as vertical functional interrelationships.
4. **Area-covering statements**: Suitable methods (of mapping, measuring and translocation) have to be provided to realize an area-covering statement without any gaps.
5. **Investigation of ecologically relevant parameters**: Typical ecological parameters have to be registered that can be considered as sum parameters (e.g. total runoff), as indicator parameters (e.g. soil temperature), as regulator parameters (e.g. infiltration capacity), as balance parameters (e.g. biomass production, soil loss) and as fundamental parameters (e.g. grain size distribution).
6. **Validation of data extrapolation**: Due to the fact that all data are measured at a point, a translocation (extrapolation) to the landscape (type) has to be done.

In connection with this we have to be aware of the peculiarities of the landscape as an object of investigation: The highly complex and complicated spatial reality has to be simplified. Interrelationships and processes are considered more in their sum effect than in detail.

Landscape ecological complex analysis starts with the **differential analysis** – the **analysis of the geocomponents** (see Chapter 3.2): Investigation of the layers near ground air, vegetation, relief, soil, geological substrate, and water. It can also be considered as a landscape ecological pre-exploration. One essential outcome of the differential analysis is to fix representative test sites.

The differential analysis is realized to gather information concerning the actual conditions of the geocomponents – considered as layers. There are many points in common with classic mapping of single geofactors. They are registered in maps completed by a description of types (e.g. list of species, leading soil profiles). On that occasion specific methods of investigation provided by several disciplines (e.g. meteorology, geology, botany) will be applied.

The pre-exploration starts with putting together available information (e.g. climate data, geological maps). It has to be continued and supplemented by subject-related ("new") investigations (Table 3.4-1).

Derived from this, there are at least two different tasks the area-covering data registration has to fulfill:

1. Registration of the distribution, the mosaic, and the variation of the geocomponents or single elements aimed at a documentation of the geocomplex's layer structure.

2. The area-covering registration of single functional parameters to recognize whether the results will be representative or not.

Due to the above-mentioned tasks of the differential analysis it can not provide solutions for the following problems:

- quantification and mutual dependencies / influences of geocomponents and geoelements as well as their annual variation,
- causal dependencies between structures and functions,
- functional landscape classification, and
- registration of turnover and balances.

Table 3.4-1: Investigations within the differential analysis

procedure	parameter examples	implementation	significance within the complete investigation	result
registration of single elements by **mapping** and analyzing existing maps	slope angle, forms of erosion, substrate, land use	field surveying and mapping, analyzing maps and air photographs	visualization of the spreading of single elements as well as of dominant dependencies between position and provision	analytical maps
registration of single elements by taking **measurements at representative sites**	distribution of precipitation and wind, soil temperature, soil moisture	measuring along a catena oriented towards the interrelationships between the relief and single features		typical field profiles, catena
registration of single elements by taking **measurements in regular networks**	groundwater level, air temperature	single measurements on several test sites to get information on the small scale differentiation of the elements	investigation of causal interrelationships between variable single elements, determination if measurements are representative or not	analytical detail maps: area maps iso-line maps
registration and presentation of geocomponents after **typifying** selected feature groups	soil types, vegetation communities	registration of the distribution pattern of a geocomponent based on a selected feature group, feature classification	recognizing the structure of an earth surface's subset, geocomponents are considered as building blocks	geocomponent maps (e.g. soil map, relief map)

All these problems can be solved by combining differential analysis with the **complex site analysis**. It has to discover **vertical functional interrelationships** at representative test sites. Practically it is realized at measuring stations or measuring fields.

Due to temporal and material limitations complex site analysis can follow two different routes:

1. Complex site analysis is restricted to only a small number of test sites equipped with extensive measuring techniques.
2. Complex site analysis is carried out at a large number of sites, where the number of parameters registered as well as the registering methods is rather simple.

The choice depends on the investigated landscape type and on the specific questions.

By providing the connection between the geocomponents (investigated in the differential analysis) the complex site analysis enables a synthetic spatial view. Within the bounds of the landscape ecological complex analysis it fulfills the following tasks:

1. In addition to the differential analysis a functional description will be given.
2. The analyzed geocomponents are connected with ecological processes.
3. The validation of the hypothesis concerning the genesis of a site mosaic derived from the differential analysis is enabled.
4. The landscape units classified temporarily at the end of the differential analysis (based on more or less structural features) can be tested with respect to the differences in the site balance.

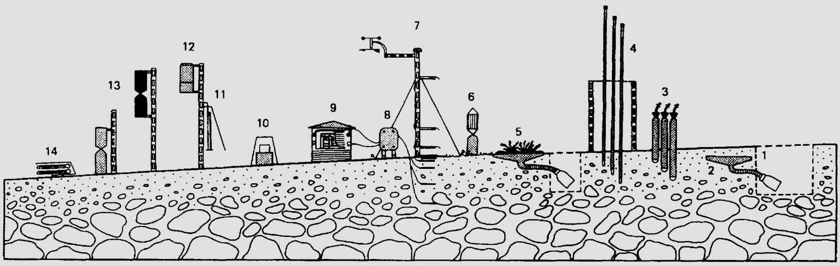

Figure 3.4-2: Equipment of a "tessera" as an example for the method of complex site analysis - geoecological investigation of the Basel polar ecology research group in the high arctic (from Leser 1993).
1 - soil profile, 2 - Funnel-lysimeter under soil, 3 - suction cups, 4 - tensiometer, 5 - Funnel-lysimeter under vegetation, 6 - fog collector, 7 - air thermistors, anemometer, pyranometer, soil thermistors, 8 - datalogger, 9 - thermohygrograph, max/min thermometer, thermistor and humidity sensor in weather hut, 10 - tank evaporimeter, 11 - Piché-evaporimeter, 12,13 - rain gauges, 14 - max/min thermometer (surface level)

Field measurements are common in many scientific disciplines. Thus measuring stations are not restricted to complex site analysis only. The peculiarities of the complex site analysis can be seen in:

- the type of correlation between the measurements,
- the position of the test sites (called tesserae, Figure 3.4-2) within an area, and
- the embedment into a superordinated methodological principle.

Important basic principles are:

- Object of investigation is the ecosystem as a whole including its matter balance.
- The spatial dimension is limited to test sites.
- The diversity of existing ecosystems within a landscape is an additional object of investigation. Measurements at several sites become estimable by the comparison between the sites.
- Several test sites will be investigated in sequences depending on functional relief.
- By integrating a network of area-covering registrations the connection between (point related) site investigations and spatial reality will be realized.

3.4.2 Implementation

The motivation for doing a landscape ecological complex analysis is our sketchy, imbalanced and spatially seldom verified knowledge about the natural conditions and functional relationships of landscapes. Hence neither in science nor in practice is sound knowledge about structure and function of landscape units available. It goes without saying that investigations have to be limited to representative areas. It is impractical (both financially as well as scientifically) to investigate every spot over a large area. But how to find a representative test site?

Scientific as well as practical criteria have to be considered when **selecting a test site**. Some of these are:

- homogeneous geological substrate,
- clear genesis of the sediment layer,
- relief should contain important slope angles and slope aspects,
- all main land use types should be represented,
- the test site should be delineated as a catchment,
- no unusual elements – like emitters of harmful substances,
- easy accessibility to save money as well as time,

- official measurement points (e.g. weather stations, runoff gauges) allow integration of the newly measured data into a larger hydro-climatic context,
- the extension of the tesserae (see Figure 3.4-2) should be 3-4 to 10 km^2, and
- no fundamental land use changes should occur at least 3 to 4 years after starting the measurements.

Based on single measurements a description of complex landscape units should be possible. This can be realized by a chain of conclusions.

The **structural investigation** focuses on geological substrate and soil. This is due to their natural importance within the landscape system (see Chapters 1.1 and 3.2). Soil is the integrating representative for all the natural processes taking place at the site. Hence it is an **integrated landscape feature** of outstanding importance that can be mapped in an area-covering manner. The second ecological main feature is the soil water balance. The balance-related site description is implemented via the soil water function due to its importance to the complex ecosystem balance and due to the close relations between soil substrate and soil moisture. The geocomponent microclimate (including precipitation) is not characterized extensively but by selected single elements. These elements can differ from site to site (e.g. amount of precipitation or temperature deviations).

The **field work** consists of mapping and measurements. At least substrate and soil types have to be mapped over the whole area accompanied by more or less detailed terrain climate measurements (depending on the landscape type) and a variable number of measurements concerning site water and/or site nutrient balance.

The single points of measurement have to be distributed regularly over the investigation area or the catchment. Following the catena-principle (see Chapter 2.6) measurement points should be arranged in a line. This is true for relief dependent parameters like temperature. A specific selection of typical sites should be realized to get local representatives for all landscape types. Additional sites should be selected according to their specific balance situation not registered by the measurements mentioned before (e.g. specific hollow positions, moist slope parts).

Beside the spatial arrangement, the temporal organization of the measurements is important, too. Not all measurements have to be carried out with the same temporal resolution. There are some possibilities: Continual measurements should have a high temporal resolution. Often sum-parameters over a one-week period are sufficient. Also measurements of single events that have an exemplary character should be made. They are especially suitable for terrain climate parameters such as temperature deviations and wind intensity. Single measurements can be compared by mapping – they register just the actual condition. They are not suitable for characterizing dynamic parameters.

The background of all the field work is **laboratory analysis**, where numbers of soil and water samples will be analyzed. The results can only be compared by applying standardized analytical methods.

3.4.3 Results

First of all a lot of **single results** in the field of geomorphology, soil, climate, hydrology, etc. are provided that can be considered separately first (Table 3.4-2). From a geoecological point of view they are interim results that will be processed in a further step to a landscape ecological synthesis.

Table 3.4-2: Single results of a complex site analysis

substrate and soil	soil water	terrain and micro climate	site related water and matter balance
- grain size distribution - substrate stacking - pore distribution - humus form - humus amount - buffering capacity	- seasonal distribution - available reservoir - amount of percolation - soil moisture regime	- gain of radiation - heat surplus - precipitation - distribution of T_{min} in sinks of cold air - distribution of wind intensity	- in- and output of nutrients and minerals - site classification according to water and matter turnover - influences on the elements of the site balance
water and matter distribution within the site mosaic	water balance of the catchment	matter balance of the catchment	
- differentiation of soil moisture conditions according to the relief - effect of soil and substrate on the lateral flow and the kind of relocated material	- water balance as a central basic parameter - share of surface and subsurface runoff - share of land surface runoff - estimation of subsurface runoff	- balances for single substances - turnover behavior of selected substances (e.g. fertilizer, manure) - interrelationship between the surface runoff and matter output	

The first step of **landscape ecological synthesis** leads to a spatial structuring of the representative landscape investigated: Single physiotopes or ecotopes are classified and delineated. This classification is based on fundamental criteria (Haase 1967, Barsch 1968, Leser 1991a, Mosimann 1984b, see Chapter 6.1):

- stable site features: relief, geological substrate, soil,
- variable inorganic site features: climate conditions, processes related to water and matter balance, and
- ecological variability.

The second step is a description of the geosystem. For years a complete description of ecosystem functions and processes has been aspired to. There are a lot of theoretical approaches to so-called conceptual models of the homogeneous natural area. But none of these models could be quantified at all up to now. So there is a wide theoretical basis but no practical verification exists. We can distinguish between four levels of ecosystem description: empirically – describing, statistically – describing, describing with the help of system analysis, and predicting with the help of system simulation.

Landscape ecological complex analysis has been practiced the first three levels for years. Level four is state of the art now.

3.4.4 Summary and outlook

Ecological planning is unthinkable without the integration of information concerning the landscape balance. Just a mapping of the single ecosystem factors is not enough. Landscape ecological complex analysis is the method suitable for this. The method itself is complete, but it could be expanded in several directions. Some of these are:

- intensification of matter balance investigations,
- intensification of measurements concerning lateral water and matter movement within the landscape,
- making the data registration more effective,
- integration of further biotic parameters, and
- integration of the analysis of harmful substances polluting the environment.

Based on this a typification/classification of nutrient balance regime could be possible just as well as an improvement of neighboring effects based on the registration of lateral processes.

Also a lot of problems in landscape planning (see Chapter 7.3) have their roots in the missing integration of information concerning the landscape balance. Landscape assessment methods as well as ecological risk analysis are limited to single stands and do not integrate effects coming from the surroundings. The better we know the correlation between landscape structure and landscape balance the more informative assessment maps we can provide based on parameters that can be measured and mapped by simple means.

Chapter 4

Landscape change and landscape monitoring

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4.1 Landscape change: history of the landscape

4.1.1 The sense of studying landscape change

Landscapes are changing continuously. This is true due to natural conditions as well as to human activities, especially in the last centuries. That is why special investigations in this field are very important. They are a prerequisite for the elaboration of concepts with regard to sustainable development:

- The early recognition and assessment of landscape changes makes corrective intervention possible; by specific regulation, undesired changing processes can be counteracted at relatively low economic expense.
- The knowledge and documentation of the ecological situation of past epochs are part of the preservation of our historical and cultural heritage.

Analysis of the historical landscape is the starting-point for the characterization of a landscape's peculiarities and its current ecological situation (including various landscape factors such as soil, water, climate, vegetation, land use). The elaboration of landscape visions (see Chapter 7.2.) can be expected "without breaks" with the previous development.

4.1.2 Major stages of landscape development

Landscape change is a complex process, encompassing ecological, socio-economic as well as cultural factors. **Natural landscape changes** can take

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place over a very long time (hundreds and millions of years), proceed very slowly, and include a range of factors such as climatic fluctuations, origin and erosion of mountains, coastal and river dynamics (Figures 4.1-1 and 4.1-2). But there are also short-term events with a duration of seconds or years and which are often manifested as natural catastrophes, e.g. floods, hurricanes, droughts, earth-quakes, volcanic eruptions, rock-slides, and avalanches.

Figure 4.1-1: Natural landscape changes can be caused by volcanic eruptions: The Vesuv volcano, Italy (Photo: O. Bastian 1992)

Increasingly, landscape changes are essentially influenced by the development of **human society** and it's means of production. In a detailed survey for Central Europe, Bernhardt and Jäger (1985) and Bastian and Bernhardt (1993) distinguished **four major stages of landscape development**:

Agricultural acquisition and use (c. 5,000-6,000 years) began with the crop cultivation and livestock rearing activities carried out by Neolithic peoples. This period lasted through the Bronze Age until the large-scale (medieval) clearing of woods ("colonization") between the 7th and 13th centuries. This created vast stretches of open countryside and changed the water balance and regional climate. There was extreme water and wind erosion particularly in the early stages, leading to widespread accumulation of meadow loam along watercourses. Shade-intolerant animal and plant species migrated to Central Europe, including species associated with crops.

Integrated development (c. 1,000 years) made wide use of all the other potentials and resources the natural landscape had to offer beyond purely agricultural pursuits, both in extensive and intensive forms. Ore-mining areas arose with a network of facilities that have largely survived to this day, such as settlement and transport as well as communication structures. The use of water for energy production and goods haulage and also for catching fish was particularly important. Hydraulic engineering created many different structures (water mills with impounding weirs, canals, ponds and channels for timber rafting, washing plants, pounding mills, fish ponds), and due to the high level of water retention extensive mosaics of wetland biotopes became established. Natural forests were increasingly disturbed and exploited for a range of resources (e.g. timber, derivatives, wood pasture, litter, hunting etc.), leading to forest management around the turn from the 18th to the 19th century. This integrated and varied utilization of landscapes vastly increased the availability of habitats, particularly because natural sites retained their varied character. Over several centuries, ecosystems and their constituent biota reflected new equilibriums. So Central Europe reached its greatest biological diversity ever around the mid-19th century.

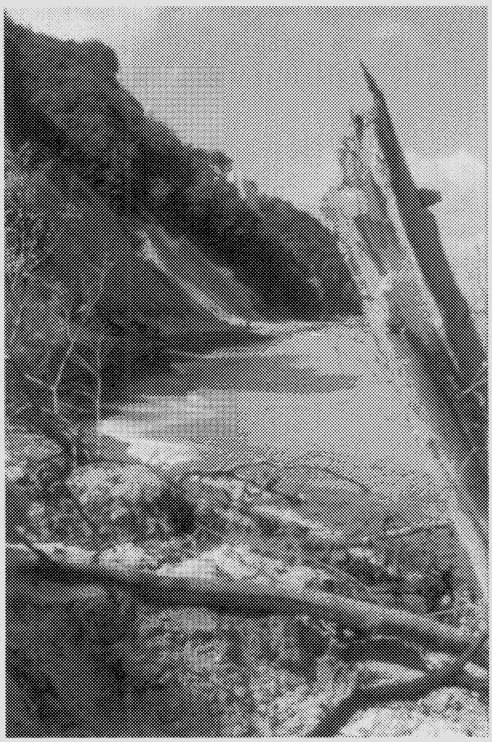

Figure 4.1-2: Also coastal dynamics are natural landscape changes: erosion of the chalk cliff "Stubbenkammer" (coast of Rügen island, Baltic Sea coast, Germany) (Photo: O. Bastian 1999)

The industrial revolution (just over 100 years) led to marked agglomeration in the settlement structure and created areas for the large-scale exploitation of resources. At the same time, the number of new and intensive uses for farmland and woodland was limited (Figure 4.1-3). About 10% of the earth's surface became completely transformed, or was sealed by residential construction, industrial development, transport routes and mining. New techniques enabled the extensive utilization of fossil fuels and the increasing sophistication of the chemical manufacturing industry. Landscapes now had to deal with substances that were new to natural systems, even though pollution emissions during this period, were largely confined to the agglomerations. The functions of running waters changed from being sources of energy to becoming carrier of goods and effluents. Water retention decreased partly through land improvement and the disappearance of ponds, impounding weirs and bogs but also as a result of growing water consumption. Agricultural production also contributed to change during this period because food had to be produced with reduced manpower: Increased mechanization reduced the demand for rural labor resulting in increased migration to the cities where the demand for industrial workers was increasing. Agricultural land, at the same time, became more homogeneous because of fertilization, land improvement and attempts to increase the depth of utilized soil horizons. The effect was a reduction of biodiversity within the landscapes. Major habitats were lost, and conservation had its beginnings with the proclamation of the first nature reserves.

Figure 4.1-3: Revolutionary technical inventions like the steam engine have expedited landscape changes: The steam driven narrow-gauge railway in Bad Doberan (Mecklenburg-Vorpommern, Germany), today a tourist attraction (Photo: O. Bastian 1997)

The scientific and technological revolution (for the last 50 years) has drawn intensively on nearly all resources and potentials inherent in natural landscapes. Large machinery systems, chemicals and automation have been used, excepting only small plots, which are difficult to reach with machines. Now all landscapes are exposed to human material and energy throughputs at levels many times above that of the past. Substances extraneous to nature have become omnipresent with an increase in diffuse deposition of and gaseous, liquid and solid phases of a variety of pollutants. There has also been a rapid increase in land use practices, which lead to interference and neighborhood effects. Biotic diversity is further reduced. In Germany, for example, 26.8% of all ferns and flowering plants are endangered and 1.6% are extinct, along with a variety of plant associations particularly those related to wetland and bogs, as well as several types of forest. This attrition of phyto-sociological diversity also applies to plant communities derived from low-input/low-output farming systems from the era of pre-industrial land use (such as extensively managed meadows and pastures, dwarf scrub heaths, segetal coenoses). In addition, most animal populations have seriously declined, among them fish (of which 71% are endangered or extinct in Germany), amphibians (58%), reptiles (75%), birds (51%) and mammals (53%), but also insects (BfN 1996). Additionally, a higher degree of mobility influences the remaining stretches of landscape that have retained their natural character. Society in the developed countries is characterized by a widespread lack of environmental consciousness and behavior. Lifestyles and consumption patterns become increasingly detached from nature. Ignorance, carelessness, and growing needs, cause even greater damage.

In a similar manner, Vos and Meekes (1999) identified the following partly overlapping stages of cultural landscape development in Europe:

Natural/prehistoric landscape (from Paleolithic till ancient Greek times): humans used nature for many 100,000s of years as a bran-tub for hunting, harvesting and cutting wood. Traces of these societies are locally found as graves or wall paintings (Lascaux: 15,000 BC; Altamira: 13,500 BC). **Antique landscape** (from ancient Greek times till early mediaeval times): Local relicts are dispersed over Europe (e.g. Stonehenge in England: c. 2,800 BC, see Figure 7.8-5 Chapter 7.8). Around the Aegean Sea the flourishing Minoan culture developed (e.g. Troy and Mycene from before 2,000 BC; Knossos on Crete from c. 3,000 BC, Figure 4.1-4).

Ploughs were applied from at least the end of the Neolithic period while cereal cultivation spread widely. Gradually nearly the whole Mediterranean area became cultivated, and although less intensive, also large parts of Central and NW-Europe. Field patterns from c. 700 BC on (like the Celtic fields) have been found on many places in NW Europe, together with remnants of settlements and graves. Vineyards, citrus groves (introduced by Alexander, c. 338 BC), olive and chestnut groves, terracette complexes, etc. are - still today - prominent inherited attributes of many southern landscapes.

Medieval landscape (from early medieval times till Renaissance): In this feudalistic period, the layout of the European landscape was gradually completed. The landscape was exploited either by farmers (private, as tenant of common lands), or by nobility or clergy. Extensive infrastructures and facilities like terracettes, stone walls, hedgerows, dams and canals were made to control an environment that was perceived as being hostile.

Figure 4.1-4: Natural landscapes were developed and changed by human activities already in antique times: Korinth and Acrokorinth (Greece) (Photo: O. Bastian 1991)

Traditional agriculture landscape (from Renaissance till 19th century, sometimes till today): The landscape became multifunctionally managed by farmers, mainly in mixed agriculture systems, integrating forests and tree pastures (e.g. for forest grazing, charcoal burning, fire-wood, timber, manuring, and all kinds of utensils), rough grazing lands (e.g. heathlands, phrygana, garriques), water systems (e.g. for irrigation, fertilization), etc.

Figure 4.1-5: Straw dolls were symbols of the traditional agricultural landscape; they vanished in most parts of Europe in the middle of the 20th century: Cereal fields near Moritzburg (Saxony, Germany) (Photo: O. Bastian 1988)

Well-established regionally differentiated land use systems developed that became the engines behind most of Europe's characteristic cultural landscapes (Figure 4.1-5). Local problems from extreme conditions (water, snow, and drought) were solved with local means. Examples are the Dutch dike-system in combination with windmills, developed from late medieval times and without which, half of The Netherlands would still be sea. In general, these traditional land use systems reached their optimum in the second half of the 19th century. At that moment, livestock had become the most important commodity, not only because of the value of meat, milk, wool and hides, but also for manure, animal power, transport, etc. (Figure 4.1-6).

Figure 4.1-6: Before introducing tractors, draught-horses (and cows) were used for the work in the field: A team while ploughing (Upper Lusatia, Saxony, Germany) (Photo: O. Bastian 1999)

In many cases these systems kept a balance between population numbers and farm production, thus achieving sustainable exploitation of local resources for long periods. However, catastrophes, periodic overpopulation and effects of wars and epidemics also occurred. Recently, once widespread traditional land use systems and their landscapes have declined rapidly in extent because of economic inefficiency: Such landscapes include the dehesas and montados, the Alpeggio and other high pasture systems, the Dutch peat polders, the terraced Mediterranean "coltura promiscua", the grazed fruit chestnut landscapes, the charcoal coppice landscapes, the Nordic mixed farming mountain landscapes, the bocage landscapes, the estuarine landscapes, the coastal wetlands (Maremme, Camarque) and Aegean and Dalmatic islands with fisherman settlements, and all kinds of local landscapes, such as the "trulli" landscapes of Puglia.

Industrial landscapes (mostly from mid-18th till mid-20th century, in many places till today): Much of the productive land became monofunctionally oriented, with bulk biomass production, onto distant markets (towns). In this industrialization stage, with its specialization and spatial segregation (monocultural fields, production forests, and closed nature reserves) much of the land became alien to the major part of society. The landscape became a "landscape at-a-distance", dominated by external markets and centralized planning control.

4.1.3 General rules of landscape development

Over the long period of human induced landscape change, there are some characteristic fundamental trends (Bastian and Bernhardt 1993):

1. In the last few thousand years, landscape changes in Central Europe have been brought about almost exclusively by material and technological advances, and social developments.
2. Each principal stage in the process has been initiated and accompanied by a radical innovation in means of production. The changes affect essential characteristics of the landscape that become relevant to society by diminishing or enhancing its potential.
3. The periods of time occupied by each of the main stages in Central Europe have become successively shorter (5,000-6,000 years; c. 1,000 years; c. 100 years; 50 years), i.e. an almost logarithmic sequence.
4. The acceleration in the pace of human intervention makes it difficult for natural processes to stabilize and the landscape (balance) to reach equilibrium. As a result, the interaction of landscape factors, and the landscape balance as a whole, has been subjected to destabilization at an increasing rate.
5. Human intervention and innovation, in the course of history, has diversified and spread to almost all elements of the landscape and its potentials.
6. At first, environmental degradation was only local and limited. It spread to larger regions, and has now reached global dimensions.
7. Changes in quality in the form of conspicuous landscape transformations, are normally preceded by "creeping" and invisible quantitative losses (e.g. in the vitality of forests before visible emission damage occurs).
8. Human induced landscape changes involve all landscape components, but to a different extent. The most dramatic response can be expected from the biotic components (flora, fauna, biocoenoses).
9. The intensity of land use, and the ecological effect is continuously rising, with technogenic elements and largely homogenized farming areas now

dominating in many regions. At the same time these "useful" ecosystems became detached from their natural roots.

10. There has been a rapid increase in the proportion of landscapes which have suffered from irreversible change.
11. Different landscapes with different assets react differently to the same type of human activity as reflected in various degrees of buffering and stress capacity.
12. Even though a number of promising attempts have been made to conserve nature (see Chapter 7.7), human intervention continues to be spontaneous to this day. There is a growing risk of disturbance and breakdowns, however, as these influences are allowed to become more frequent and complex.

4.1.4 Current trends

Current trends in European landscapes are related to the following **major changes in land use** (WLO 1998):

- intensification, mechanization and overdevelopment in agricultural use - especially in North-western Europe - accompanied by marginalization, land abandonment and underdevelopment in Southern Europe,
- urbanization, increasing infrastructural networks, intensification of transport and recreation,
- environmental and ecological stress resulting from, for example, eutrophication, chemical pollutants, acid deposition, falling water tables and habitat degradation
- promising experiments and initiatives in nature conservation, nature development and ecological farming.

Our so-called **postmodern landscapes** represent the culmination of dramatic changes in production and information technology as well as by demands from society. The economic base of the landscape household is also completely transformed. Land use profits in one region are expanding spectacularly, but diminish equally spectacularly in other regions (Vos and Meekes 1999).

Today, landscapes are strongly influenced by the ongoing **globalization process**:

- economic globalization caused in the interdependence of trade and markets,
- globalization of communications, and
- almost complete globalization of the aspirations towards a common unachievable lifestyle.

Consequences of globalization imply the appearance of new invasive species and pathogens, and particularly a total disruption of previous land uses and landscape boundaries. The trends of such landscape modifications can go towards a further and excessive use of natural resources leading to deforestation and desertification, or conversely towards the abandonment of fertile agricultural lands because of economic imperatives of lack of competitiveness ("human desertification"). In any event, the face of the earth will change in a few decades, much before the likely appearance of the human-induced climatic global change (Di Castri 1995).

Because of ongoing influences from unsustainable land use, the marginalization of agriculture, the almost free availability of energy and nutrients, and the complexity of structures and processes, together with their global interconnection, the landscape has increasingly lost its significance as a reflection of the human society of a particular region (Muhar 1995). The socio-cultural identity of landscapes as a source of inspiration for aesthetic, educational and scientific information and a healthy environment for living is degenerating rapidly. Concurrently, long-term economic potential is being negatively affected by short-term decisions. The loss of potential use is directly connected to the **unsustainable exploitation of natural resources** (WLO 1998). The development of our "shopping society" with its multiple demands results in our postmodern landscapes in a mosaic of different landscape types. These display different intensities and styles of control (high → low) whose products are all desired by society (Vos and Meekes 1999):

- industrial production landscapes: landscape as an industry,
- overstressed multifunctional landscapes: landscape as a supermarket,
- archaic traditional landscapes: landscape as a historical museum,
- marginalized vanishing landscapes: landscape as a ruin, and
- natural relict landscapes: landscape as a wilderness.

Whereas, positive **perspectives** for the future of cultural landscapes of Europe are based on the following observations (Vos and Meekes 1999):

1. A rich and stable society demands a broad spectrum of landscape functions from our landscapes, including primary production, nature, recreation, and housing.
2. Many farmers move towards multifunctionality, including landscape management, when they gain profits from it. The spectrum of farming and management styles, includes those that call themselves "ecological", "biological", "integrated", "biological dynamical" or "organic" has never been broader all over Europe (see Chapter 7.5).
3. There is a growing political and public engagement with a "healthy" countryside as part of regional cultural heritages.

4. These developments coincide with a shift towards decentralization and denationalization, which favors a "Europe of the regions" with their own cultures, products and landscapes.

4.1.5 Landscape change in different European regions

Although landscape changes follow common regularities in different regions, there are many specific peculiarities: different landscapes with different resources and potentials react in a variety of ways to the same type of human activity. The trends differ between Western, Eastern (and Southern) Europe. They also vary considerably between countries within a regional group, and between regions within a single country (Krönert et al. 1999). There are also different environmental impacts (with regard to nature and intensity) with each locality. A number of comparative locality studies are required to identify the causes of the varying characters of landscape changes. Such a series of studies was realized by the project EUROMAB (Krönert et al. 1999, Ryszkowski and Balazy 1992).

Generally, in favorable areas an increasing intensification of agricultural production takes place, connected with population increase (concentration) and improvement of infrastructure (e.g. for traffic); in less favorable areas extensification, withdrawal, or even total land abandonment and exodus of the population occur, the so-called **marginalization**. Certainly it is needless to say, that landscape changes are not limited to Europe, but they are a common phenomenon throughout the world.

Figure 4.1-7: Marginalization (land abandonment and population exodus) of less favored regions is a widespread phenomenon today: Mediterranean landscape, isle of Cres (Croatia) (Photo: O. Bastian 2001)

Land abandonment is the most conspicuous process, coupled with development in most industrialized countries. Among the huge number of publications from many countries, only some examples can be mentioned: Farina (1998) in Italy, Brandt et al. (1999) in Denmark, Mander and Palang (1999) in Estonia, Bacharel and Pinto-Correia (1999) in Portugal, Kamada and Nakagoshi (1997) in Japan. Generally people move from the uplands and badlands to lowlands and industrialized areas. The landscape dominated by human use over many millennia is abandoned and a secondary succession modifies vegetation cover and consequently animal assemblages. In particular across the Mediterranean land abandonment, especially on mountain ranges, has been very common and widespread over the past 50 years (Figure 4.1-7). One relevant consequence is the change in landscape mosaic owing to woodland resurgence.

Another group of studies focuses on the ecological consequences of political changes in former communist countries (e.g. Bastian 1991a, Bartoš et al. 1994, Csorba 2000, Čudlinová et al. 1998, Krönert 1999, Lipský 1995). Changes of land ownership, economic conditions (trade, markets, and subsidies), technological possibilities, and awareness are relevant factors.

4.1.6 Investigation of landscape changes

Principal questions in research on landscape changes are according to Bastian (1999a) e.g.:

- Their speed from t_1 to t_2. What is the temporal distance between the causes and the effects of changes?
- The spatial dimension of changes. At which level of ecosystems or landscapes do the changes take place and are they ecologically significant? Are the changes locally bound, singular cases or widespread common phenomena?
- The reversibility or irreversibility. Are the changes reversible? If yes: at what expense and over what period of time?
- The acceptance of changes by society.

The following **working steps** for the investigation of landscape changes are proposed (Bastian 1999a):

1. choice of forms of change, and of suitable methods for analyses/ diagnoses/ evaluations, necessary indicators and representative test areas,
2. collection of historical and actual data (for t_1 and t_2),
3. interpretation of current social and economic changes with regard to ecological conditions and landscape functions (see Chapter 5.2),
4. identification of driving forces and effective mechanisms/ causal connections, and

5. identification of trends, prognoses, and management for future landscape development.

The scope of investigations about landscape changes may range from a limited number of landscape components, which have an indicator value sufficient to reflect the condition of the ecosystems concerned, to comprehensive surveys of landscape development covering a variety of phenomena and interactions. The most promising approach to deal with a multitude of variable landscape features is limited to a few meaningful indicators. One of these is **land use** (land cover), which is so significant because it is involved, directly or indirectly, in all the demands society makes on nature. Land use data can provide information on the status of the biota within a landscape.

As a case study, for the "Kleine Spree" floodplain (biosphere reserve "Upper Lusatian Heath and Pond Landscape", Saxony, Germany) selected land use types (forests, grassland, arable fields, settlements), and landscape elements (standing and running waters, paths and roads, single trees, groups of trees, woodlots and hedgerows, and the borders between different land use types) were analyzed for four periods (points in time: 1825 - 1884/86 - 1936 - 1987/91) with the help of digitized topographical maps 1:25,000 (Figure 4.1-8). Extent and speed of changes increased more and more, and the most important differences could be established between the last two phases (1936 - 1987/91). The intensification of agriculture is regarded as the main cause.

All land use types and most of the landscape elements are affected (Table 4.1-1). Generally, the size of patches (e.g. parcels of arable fields: from 2.5 ha in 1825 to 14.0 ha in 1987) increased, and the number of landscape elements, edges (ecotones), and therefore landscape heterogeneity decreased.

Table 4.1-1: Land use changes in the "Kleine Spree" floodplain (ha/%) (from Schulze in Bastian 2000a)

phases (points in time) land use type	1. 1825 *(100 %)*	2. 1884/1896	3. 1936	4 (1987/1992)
forests/fenwoods/ coppices	76/?/8 (Σ 84)	31/10/32 *(87 %)*	84/?/24 *(129 %)*	81/19/20 *(143 %)*
grassland / moist grassland	354/88 (Σ 442)	374/64 *(90 %)*	431/19 *(102 %)*	265/59 *(73 %)*
arable fields	237	227 *(96 %)*	181 *(76 %)*	307 *(130 %)*
settlements: buildings / gardens and open spaces	21/8 (Σ 29)	25/8 *(114 %)*	27/10 *(128 %)*	38/7 *(155 %)*
standing waters (ponds)	188 ha	208 *(111%)*	201 *(107 %)*	170 *(90 %)*

Special attention was given to the running waters themselves ("Kleine Spree" river, tributary rivulets and ditches). With a special method (according to Giessübel 1993, modified for topographical maps), the naturalness of water bodies morphology was assessed. Step by step, a decrease of "natural and only slightly impacted" sectors (of running waters) took place 1825: 71% → 1884/86: 58.5% → 1936: 33% → 1987/92: 16%). Morphological changes are: straightening and canalization (reclaimation), construction of weirs, creation or removal of ditches and riparian woods (Martin 2000).

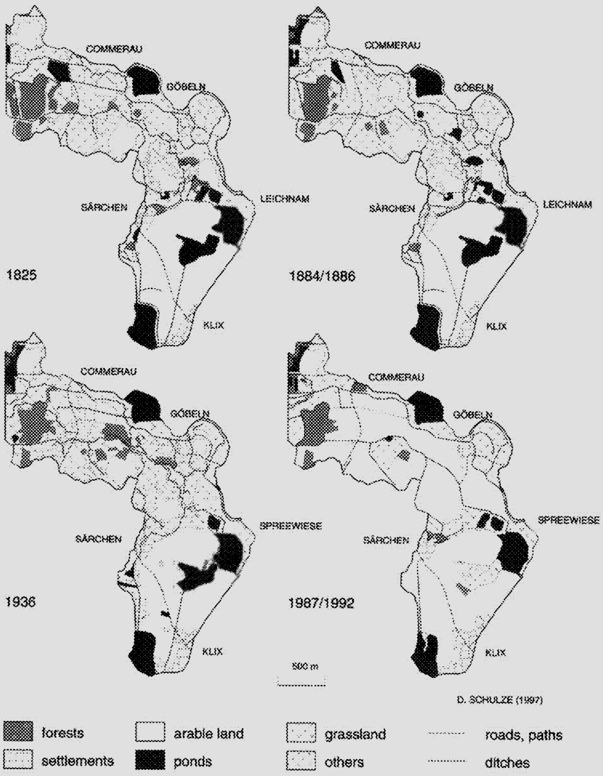

Figure 4.1-8: Land use changes in the "Kleine Spree" floodplain (Saxony, Germany) (from Schulze 1997 in Bastian 2000a)

The comparison of topographical maps, however, conveys an incomplete picture of landscape changes only. Information on land management has to be included. The consequences of higher **land use intensities** (e.g. application of fertilizers, biocides, irrigation, drainage, reduction of crop diversity - vanishing flax, millet, buckwheat; soil compaction, surface sealing) must not be ignored. Furthermore - apart from subjective aspects of mappers - there had been different mapping instructions for the map series (e.g. for the registration of linear woods, borders between elements like swamps, reeds, wet and fresh grassland).

Extensive research concerning **small biotopes** and their pattern in Danish agricultural landscapes has been done by Brandt et al. (1999). Small biotopes are an integral part of the agricultural land-use system. In many ways changes in small biotopes reflect changes in agricultural land use. As a consequence, small biotopes may be used as indicators. From the 1960s onwards, the industrialization of agriculture had been accompanied by a tremendous decline in most types of small biotopes, resulting from the establishment of larger fields on holdings of rapidly growing size and supported by a widespread tendency towards mono-cropping, especially of barley. However, over the last 15 years, this trend has been reversed. A stabilization first observed at the beginning of the 1980s has been followed by a period of increase, which seems to be continuing during the 1990s.

For a number of years, geographers and particularly landscape ecologists have described **vegetation** as a main ecological feature of the landscape (see Chapter 1.2.4). Vegetation is the most conspicuous biotic component; it covers most of the earth's continental area but also grows in the aquatic regions and even in the oceans. Along with the fauna and the water balance, it is among the most unstable variables in geosystems and therefore one of the easiest to alter.

Changes of **vegetation diversity** concern most parts of the world. These changes are visible at different levels of vegetation organization, e.g. in the local flora, in the species composition of plant communities, in the list of local phytocoenoses (typological richness), and in the spatial distribution of vegetation units (Solon 1998).

The problems of vegetation changes can be analyzed from different points of view. Among others, the following aspects seem to be most interesting (Solon 1998):

- the changes of potential natural vegetation (which is defined as the vegetation representing the present abiotic site conditions including all essential irreversible changes) as a manifestation of abiotic environment dynamics,
- the changes of actual vegetation and the influence of land use upon the vegetation structure (decrease or increase of naturalness), and
- the changes of biodiversity.

By drainage of agricultural areas the groundwater level is lowered and, thus, the **potential natural vegetation** on hydromorphic sites changes. Potential riparian forests vanish in consequence of casing rivulets. In a Saxonian test area, almost all bogs got lost as sites of alder swamp forest. Moist oak forests (Molinio-Quercetum) are affected and tend to develop now towards drier variants. There are also modifications of the potential natural vegetation caused by nutrient inputs due to emissions (Bastian and Röder 1998).

Comparisons of vegetation records at different times (if available) offer compelling evidence of long-term ecological change. As a consequence of intensive agricultural use, profound changes in **grassland vegetation** occurred in most parts of Central Europe during the last 30 years. Completely new types of intensive grassland developed. Up to the early 1970s, in test areas of Saxony (Germany) "semi-natural" meadow communities rich in species dominated. These types showed a clear succession of soil-moisture stages. Intensification and amelioration leveled site differences, resulting in relatively uniform grasslands. The rapid decline in diversity may be less attributed to the disappearance of species than to the large-scale displacement of diverse meadow communities by monotonous types of grassland. The assessment of grassland types in a test area in the Saxonian lower mountain region (Germany) between 1957 and 1994 shows the following development: While all meadows had highest habitat values (they supported a high biodiversity) in 1957, by 1994 almost all plots had deteriorated or had become arable fields (Bastian 1999a, Bastian and Röder 1998).

Over the past decades also **arable land**, has been subjected to intensified cultivation and thus to profound changes in its spontaneous vegetation. These changes refer to both the range of species and the dominance of certain wild field plants. According to Hilbig (1987) and Schlüter et al. (1990), there has been a general decline chiefly in such species which

- do not survive deep tilling and herbicide application,
- settle on extreme sites such as limy, acid, poor, or shallow soils,
- no longer find the necessary soil moisture after draining,
- grow mainly on stubble or fallow fields and disappear because ploughing is now common immediately after harvest,
- are associated with ever more rarely grown special crops (e.g. flax),
- were found mostly in small, low-yielding fields that were difficult to cultivate, and thus have been transformed into grassland or forest.

The intensified use of agricultural land and increased environmental stress has consequences for the entire surrounding landscape including **forests**. Chiefly small woods are exposed to direct impacts from adjacent farmland. Nutrient input from fruit-plantations into small wooded valleys within a large fruit-growing area south of Dresden (Saxony, Germany) has led to a considerable increase in eutrophication of near-natural deciduous forests. The floristic impact is realized via an increase in abundance of nitrophilous herbaceous plants along woodland fringes on the plateaux and of ruderal species in woods on the upper slopes of the smaller valleys (Bastian 1987).

In addition eutrophication effects appear to have extended to larger forest areas. In secondary spruce and pine forests in Western Lusatia (Saxony, Germany), more than 40 years ago, the herbs and moss layers were dominated by acidophilous plants. These indicators of poor soils and raw humus - first of all many mosses and lichens but also *Vaccinium myrtillus* and others

- declined sharply. However there has been an increase in species associated with higher substrate fertility. Typically, these changes begin at the edges of forests and then extend gradually into the stand. A similar effect is produced by the thinning of secondary coniferous forests resulting from the injurious effect of pollutant deposition. Increased incidence of light and airborne nutrients also accelerate the decomposition of forest litter and raw humus. This increases nutrient availability which in turn promotes the establishment and persistence of nitrophilous, herbs and grasses (Bastian 1987).

The comparison of vegetation records with the help of Ellenberg's **indicator values** (Ellenberg 1979, see Chapter 3.2.3) shows interesting results, as well. For example, the average pH-value of arable fields in the Moritzburg small-hill landscape (north of Dresden, Saxony, Germany) has risen from 4.4 in 1963 to 5.8 in 1984. This corresponds to a shift in the pH-value of the topsoil from lightly acid to almost neutral. An increase in the average nitrogen index from 5.1 to 6.2 indicates a general rise of the trophic level (Bastian 1986, 1987b, Figure 4.1-9). In this test area, dry hilltops not suited for agricultural use often bear small stands (about 0.3-5ha) of pines, oaks, hornbeams, and birches. The pH-value of these woodlots rose from 3.6 to 4.4, the nitrogen index from 4.0 to 4.7. As there has been no intensification of forest exploitation, nutrient input from the adjacent fields, above all by air-borne fertilization, must be taken into account in addition to the general atmospheric pollution by industrial emissions.

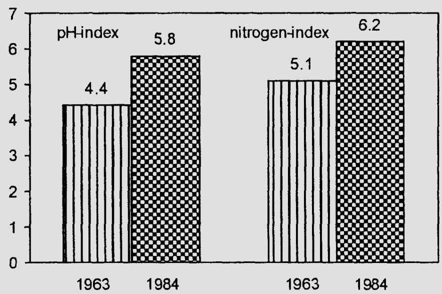

Figure 4.1-9: Average changes of soil properties in arable fields (Moritzburg small-hill landscape, Saxony, Germany) between 1961 and 1984, established with the help of vegetation records (methodology according to Ellenberg 1979) (from Bastian 1986, Bastian and Röder 1998)

4.2 Landscape monitoring

4.2.1 Definitions and a short survey

With regard to the fast ecological changes on earth, and growing environmental problems, the importance of a scientifically sound and systematical monitoring as a tool of environmental protection is more and more acknowledged (World Commission 1988), since many tendencies in nature and environment can be grasped and predicted only by long-term observations and measurements.

Monitoring is defined as a system of observations of changes in the ecosphere, being influenced by human activities. It contains according to Vahrson (1998):

- the observation of factors influencing our natural environment,
- the assessment of the actual environmental situation, and
- the prognosis and assessment of the further development (future changes) of nature and environment.

Long-term ecological research (LTER) has so far no tradition, (not only) in Germany. This follows from the emphasis on funding short-term research work. This is closely connected to our apparent bias for experimental studies, deeply founded upon our persuasion that "serious science" requires experiments. Only a well designed combination of experimental and observational approaches based on a conceptual model will produce a tangible LTER results in theory and it's application (Haber 1989).
Several **environmental programs** of the United Nations (UNEP, MAB) try to record global changes. One example is the Global Environment Monitoring System (GEMS) of UNEP with its air, food, health, water and radiation sections. To a large extent, international activities are poorly coordinated hence monitoring initiatives operate largely in isolation. There are also several programs embracing a number of European countries, e.g. the German, Dutch and Danish "Trilateral Monitoring-Concept for the Waddensea" (tidal shallows). While many different organizations advocate integrated transboundary monitoring of a range of indicators, implementation has been slow. This reflects the complexity of some indicator systems, their high cost and lack of political enthusiasm.

National programs are (in Germany): the so-called "Umweltprobenbank" (environmental sample bank), the air quality network (measuring air pollution), monitoring of forest damages and plant and animal population trends, the "Integrative Ecosystem Monitoring" (see Chapter 4.2.3).

Tasks of an environmental monitoring program are (Müller 1996):

- to check important environmental parameters,
- to provide data for environmental assessments,
- the early detection (diagnosis) of environmental impacts and changes,
- to sample basic data for environmental reports,
- to inform political decision making,
- to take care of protection against unfavorable changes,
- to predict the future development of the environmental situation, and
- to measure the performance of environmental protection measures.

Sectoral monitoring programs are carried out e.g. by the meteorological service: weather, radioactivity, phenology, radiation, ozone, vegetation cover (by NOAA-satellites), Global Atmosphere Watch. Other programs are related to waters, e.g. the water-bearing and quality of rivers, level and quality of groundwater. The soil monitoring program covers biological, chemical and physical soil parameters (e.g. contents, inputs, outputs of matters, compaction, and erosion). Monitoring programs were developed especially for the area of nature conservation. The Fauna-Flora-Habitat-Convention (FFH) implies the obligation of all members of the European Community to report on the preservation of protected areas of the "Natura 2000"-network in intervals of six years (see Chapter 7.7).

Integrative monitoring concepts should help to recognize the environment as a system with abiotic and biotic influences. They should aim to partition spatial and temporal variance between natural as well as anthropogenic drivers of ecosystem change. Monitoring should therefore operate at large scales over long periods. .

The fundamental demands on sector-embracing ecological monitoring concepts are (Vahrson 1998):

- complex approach considering the different environmental media and the ecosystem as an entity,
- choice of representative sample sites, ecosystems and plots,
- intelligent organization of data sampling, exchange and combination,
- statistically based sampling and analysis,
- systematical data sampling and documentation, continuity of observations, and comparability of applied (standardized) methods,
- efficient data processing, the application of Geographical Information Systems (GIS) for the documentation and updating of harmonized data banks (see Chapter 6.2), and
- national and international cooperation.

Landscape monitoring deals with the observation, assessment and prognosis of the ecological situation of landscapes with special reference to the consequences of human activities. Spatial structures in the chorological dimension, such as fragmentation, neighborhood-effects, distances, relation of edge to area are of crucial importance. Whereas most monitoring programs have a strong sectoral orientation or try to grasp very small-scaled processes in the topological dimension, a landscape monitoring should analyze landscape changes in an integrative manner on a medium scale (chorological dimension). Special attention should be given to the registration of landscape structures, processes and patterns (Vahrson 1998).

4.2.2 Remote sensing maps and other tools

Satellite remote sensing has already found wide application since land-use changes are fairly easy to identify when records from different years are compared (multitemporal image analysis). Remote sensing is an excellent tool for identifying regions with rapid changing land uses that should be monitored on a systematic basis (see Chapter 6.3).

The CORINE Land Cover Maps (1:100,000, based on visual interpretation of Landsat-images) provide a suitable data basis for the identification of 44 land cover categories in Central Europe. In addition, repeated recording of **biotope type and land use maps** on the basis of airborn color-infrared images (CIR, scale 1:10,000) can be utilized. This exercise can be combined with the selective mapping of valuable biotopes (scale of the maps: 1:25,000). Also topographical maps, which are updated from time to time, can provide valuable information.

Recent advances in computer technology (high-resolution scanners, global positioning systems, digital photogrammetry, digital image-processing and GIS) opened new possibilities for the extraction of quantitative vegetation data from **aerial photographs** (see Chapter 6.3). Carmel et al. (1999) developed a generic approach, based on image processing of historical aerial photographs with a GIS environment, for measuring, analyzing and modeling long-term patterns of vegetation dynamics on landscape scale and tested it on the example of case studies from Mediterranean and desert ecosystems. The approach enables analysis of vegetation dynamics at a combination of spatial resolution (10-50 cm), spatial extent (1-50 km^2) and temporal scales (10-50 years) that was not possible before. Currently, aerial photographs provide one of the best sources of information available for research of long-term vegetation change.

4.2.3 Environmental monitoring in biosphere reserves

For comparable monitoring programs and activities the world-wide network of **biosphere reserves** is especially suitable because this type of protected areas (UNESCO 1995, Figure 4.2-1):

- covers most of the typical ecosystems of the earth,
- includes a gradient of different intensities of land use,
- contains areas which are influenced by human utilization and threats but also strictly protected areas,
- guarantees a long-term protection by law,
- has own authorities and a scientific staff which are able to organize protective, research and monitoring activities,
- has the special task for public relations work,
- favors the exchange of data due to the membership in national and international working groups / expert teams / organizations.

Figure 4.2-1: For comparable monitoring programs and activities the world-wide net of biosphere reserves is especially suited: Part of the biosphere reserve "Upper Lusatian Heath and Pond Landscape"(Saxony, Germany) (Photo: O. Bastian 1999)

A recent phase in the development of ecosystem research within the MAB-program, has been the implementation of a pilot project centred on the German biosphere reserve "Berchtesgaden" in the Alps the "**Conception for an ecosystemic environmental observation** - pilot project for biosphere reserves" ("Integrative Ecosystem Monitoring" = "Ökosystemare Umweltbeobachtung" - ÖUB) (Schönthaler et al. 1997, Figure 4.2-2). The aim is a harmonized, comparable environmental monitoring program which considers the complexity of ecosystems, and which is oriented towards global, national and regional problems. Essential characteristics are:

- parameters based on 1. models, 2. data, 3. questions (problems),
- creation of a core data set which can be applied to all biosphere reserves,
- analysis of matter balances and flows by an ecological balance model,
- propositions for a unified spatial reference, and

– framework (guiding principles) for the elaboration of regionalized observation programs.

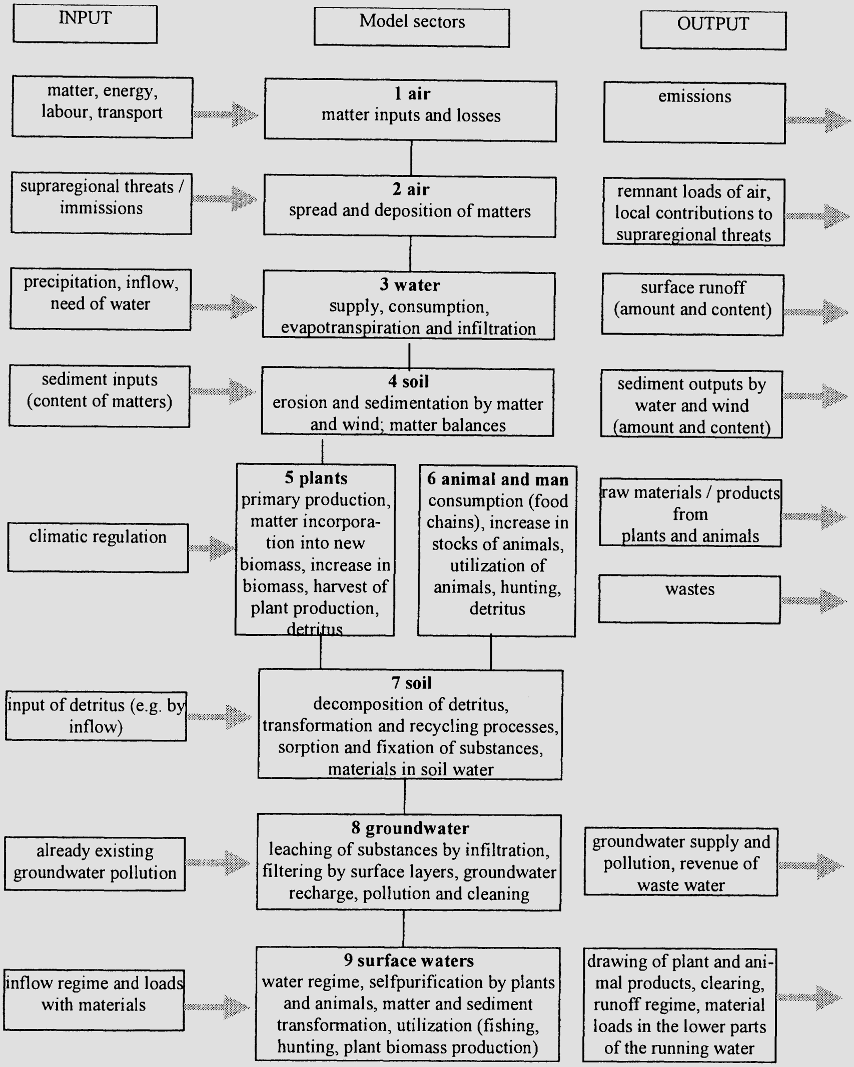

Figure 4.2-2: Sectors of the balance model. The total calculation (Model sector MS 1-8) is carried out for every ecosystem in the test area; finally the water model (MS 9) is calculated. The inputs and outputs shape the material-energetically network regulating the ecosystem and connecting the whole landscape system, their intensities, dynamics, reaches and balances describe the natural balance of the analyzed area and its stability and vulnerability to potential damage and external regulation (from TLW 1994, modified)

With the **model oriented approach**, hypotheses for causalities are drawn up and verified afterwards in test areas with ecosystems of different types. This way the parameters regulating ecosystems can be recognized. Some of them can be used as indicators and be separated from others that are not relevant. The **data oriented approach** guarantees that only such variables are considered in the balance model, which can be ascertained anyway. The result is a collection of data sampling methods for specific sectoral research branches and for current routine measuring programs. The **problem oriented approach** supports the elaboration and establishment of regional monitoring programs. On the one side, regionally important parameters are selected, on the other side, questions and problems being important for the each region are identified.

4.2.4 The "Ecological Area Sampling" (EAS)

In Germany, the "Ecological Area Sampling" (EAS) was developed as a new tool integrating data on nature and landscape structures and their development. For the first time data will be collected in a systematic, representative and periodical manner across the entire national sampling domain (Hoffmann-Kroll et al. 2000, Seibel et al. 1997). EAS should be integrated into the "Environmental Economic Accounting" (EEA). EEA provides information from a national point of view both for the pressures of economy on the environment and for responses to improve the environmental conditions.

For EAS, data on the landscape quality, the biotope quality, and the occurrence of species in biotopes are collected in periodically monitored sites that were selected at random. EAS can be divided into two levels (Figure 4.2-3). At the first level, indicators of landscape quality (Table 4.2-1) and of biotope quality are covered for the sample units (size 1 km^2). For this purpose, aerial photographs are used to determine the biotopes existing in a given sample area. Subsequently, the landscape is examined (through a field survey) and the biotopes checked for their coverage or, where necessary, further specified by means of a biotope classification comprising some 500 items. Moreover, the field survey allows the coverage of small biotopes that are not visible on aerial photographs. For important biotope types, the field survey also serves to cover additional variables on the biotope quality. The results of aerial photograph interpretation and field survey then are digitized and stored in a GIS (Arc/Info). Subsequently the data are raised to higher levels such as land classes (see below) or biotope types. Results are evaluated both for the overall areas of the sample units concerned (landscape quality) and for individual biotope types (biotope quality).

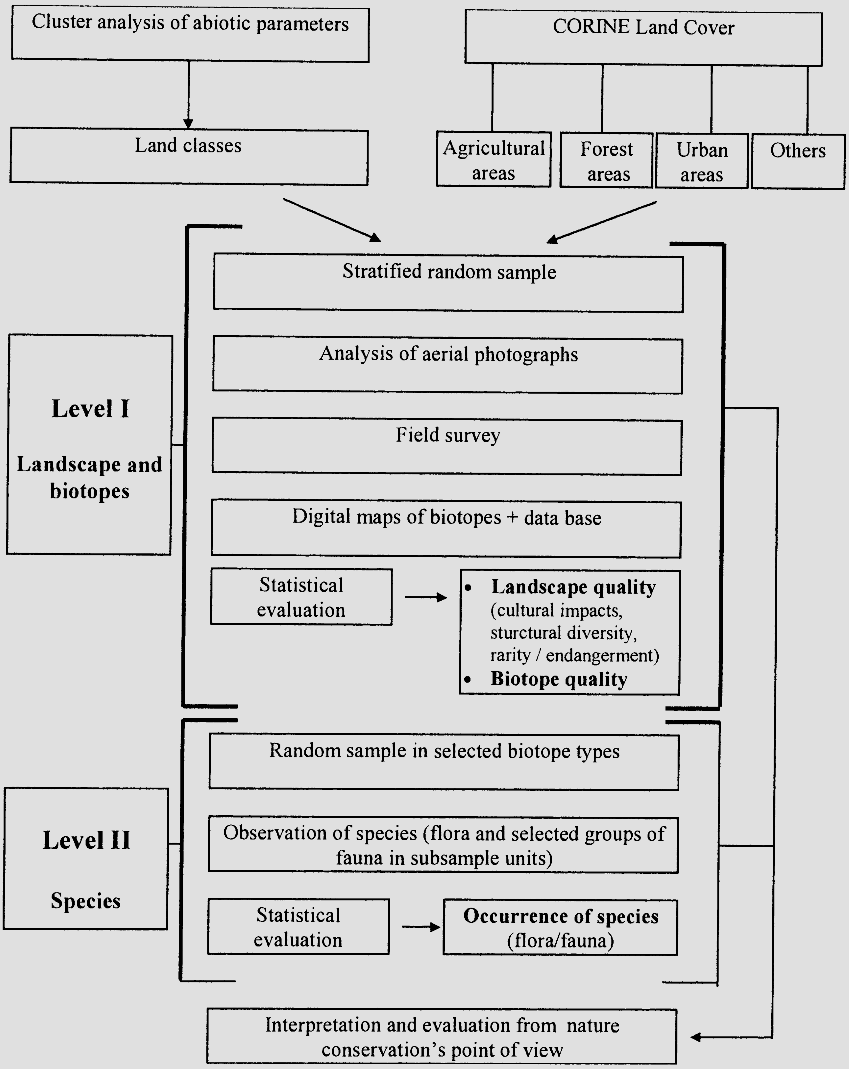

Figure 4.2-3: Scheme of the Ecological Area Sampling (EAS; from Seibel et al. 1997, modified)

At the second level, these results are supplemented by an analysis of the species (plants and some groups of animal species) existing in randomly selected subsample units within the sample areas of the first level.

Only when landscape quality and biotope quality (level I) are linked with the stock of species in biotopes (level II) it will be possible to achieve a satisfactory assessment of the ecosystem quality with regard to its physical structure, as is planned for the indicator system.

Table 4.2-1: Indicators of landscape quality in agricultural patterns (from Seibel et al. 1997)

item	indicator
cultural impact / intensity of use	– artificiality – soil sealing – risk of erosion of arable land – fragmentation
structural diversity	– biotope diversity – plot size of agricultural areas – elements with linear features – small biotopes – spatial distribution of structural elements
rarity / threats	– occurrence and spatial distribution of threatened biotopes

Since the appearance of landscapes and the occurrence of species heavily depend on the local land conditions, a classification of Germany into 28 land classes was developed; each of these land classes is characterized by a largely homogeneous natural composition (regarding geology, climate, soil, hydrology and morphology). For each group of biotope types, specific forms of survey were designed. Primary data to be collected are number of species per plot, degree of soil coverage, height and number of vegetation layers, total degree of soil coverage and species belonging to the layers.

For the faunistic study, groups of species were selected on the basis of a catalogue of criteria (indicator value, time required for investigation, feasibility, acceptance). Among the invertebrates, these groups are butterflies, dragon flies, locusts, carabid beetles and water molluscs, while among vertebrates the birds and amphibia were chosen.

4.2.5 Other examples

In Denmark, a monitoring approach was developed for agricultural landscapes involving the classification and mapping of **small biotopes** (see Chapter 4.1.6). The main purpose of the "**Agricultural Landscape Monitoring**" in Estonia (Sepp et al. 1999) is to define changes in land use structure within different types of agricultural landscapes (intensive and extensive land use). The conception is based on the connection between landscape structure indicators and the characteristics of the ecological status of agricultural landscapes (soil micro-organisms, number of earthworms, pollinators), as well as compensating elements (woods, wetland and semi-natural meadows, heaps of stones, stone fences, ecotones).

The German concept for a "**National Monitoring of Ecological Effects of Agriculture**" (Geier et al. 1999) contains a set of indicators which are related to 15 spheres of environmental effects: biodiversity, landscape scenery, soil functions, drinking water quality, eutrophication, acidification, green-house effect, consumption of resources, ecotoxicity, human toxicity, nuisances caused by smell, suitability for animals, diversity of crops and domestic animals, ozone breakdown, use of genetically modified organisms.

The "**Landscape monitoring concept of the Saxon Academy of Sciences**", alluded to above, will be repeated at in regular intervals, in hierarchically chosen test areas (local, regional, country level), such landscape characteristics shall be investigated that essentially regulate landscape balance and functionality. For the assessment, landscape functions (see Chapter 5.2.) are determined. These functions will be tracked by specially designed quantitative indices, which are sensitive to small magnitude changes in ecosystem properties. Both assessment results and monitoring indices shall integrate the multitude of different data, in order to enable a compatible and reliable set of scientific statements to be made as a basis for landscape-related decision-making. The choice of methods considers the changeability of data and landscape characteristics on the one hand and the suppression of possible artifacts in measuring and computing over some years on the other hand. In particular, the transformation from the parameter to the value level, supplies important information for users and decision-makers about the present ecological situation and changes, and concerning necessary measures of risk management, protection, and restoration. According to their importance and the expense of data sampling, we distinguish between the basic and the additional program (Table 4.2-2).

Table 4.2-2: Data in the landscape monitoring concept of the Saxon Academy of Sciences

landscape component	parameters: basic program	parameters: additional program
relief	– small relief elements	
soil	– thickness of the upper soil-layer	– nutrient content
	– humus content	– humus quality
		– heavy metal content
		– soil density of the plough sole
		– pH at the upper soil layer
		– wet patches
		– nutrient storage capacity
water	– water flow	– physical parameters (pH, redox)
	– water quality	– water retention
	– morphological structure	
climate	– interpretation of data from the meteorological service:	– own measurements of selected meteorological parameters
	– precipitation	
	– potential evaporation	
	– air temperature	
	– immission (SO_2, NO_x, O_3)	
biota	– biotope pattern	– habitat structures
	– vegetation (phytosociological	– small biotopes

landscape component		parameters basic program		additional program
		records)	–	plant and animal species
land use	–	land use classes	–	tillage methods
	–	surface sealing	–	use of fertilizers
	–	crops	–	husbandry

4.3 Landscape prognosis: future landscapes

4.3.1 Introduction

The prognosis of future landscapes has not been a very important issue in landscape ecology up to now. The physical and chemical site conditions were regarded to be more or less stable at the landscape scale, even when small scale changes mightl occur. Then, the development of landscapes would be directly controlled by human management activities.

This could be reflected in scenarios, but the major problem with scenarios is, that they are a mere collection of assumptions. They can hardly be proven. However, such assumptions have to be made, because the future direction of development in a landscape is determined by decisions in human societies. Such decisions are rather based on the socio-economic standard and financial mechanisms, than on environmental conditions. These add another **uncertainty** to the conceivable directions of future developments. These decisions are controlled and modified by zeitgeist, prosperity, and by the development of global markets. With increasing importance, environmental problems will contribute to the questions the society will ascend to the strategies that are developed.

Future changes are very much depending on the goals of a society, its needs and fears, and on the benefit that a certain management of land or a certain development might promise. **Social expectations** are changing rapidly compared to natural processes in the development of landscapes. Looking at possible future developments, such deviating expectations and needs within and between societies have to be kept in mind (see Chapter 7.2). It causes the necessity to develop competing scenarios for one specific landscape, which might become relevant if a certain setting will be implemented (Figure 4.3-1).

The focus of **landscape prognosis in the past** was laid on the planning of differentiated land use, infrastructure and tourism. According to this, particularly socio-economic developments were considered and related to site quality, climate, soils and relief. The feedback of the imbalanced landscape system to human activities is explicitly integrated into landscape ecology only since the 1990s. This is also true for the regional and global changes of the environment, that are not directly related to the management of landscapes themselves. The paradigms of landscape ecology had to shift and adapt processes with a new quality in space and time. Another aspect, which might explain the small importance of landscape prognosis in the past is the complexity of landscapes. Complex systems are difficult to predict.

Landscape ecology concentrated very much on the description and analysis of patterns and processes in recent landscapes. Related to this, historical developments and former causes for the recent environment have been investigated (see Chapter 4.1). Until the late 20th century it was assumed more or less implicitly that future developments would be as slow as they had been in the past. This is true perhaps for most geomorphodynamic processes, for soil development and for the establishment of most of the species and communities in landscapes. It will no longer hold true for species invasions and species extinctions, which become more and more important. As an effect, processes and mechanisms that formerly had been rather stable, rare or slow could be promoted now.

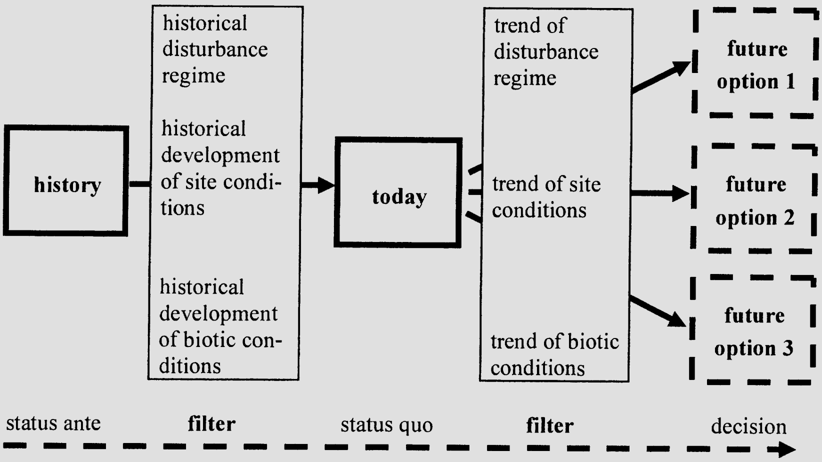

Figure 4.3-1: Scenarios of future developments of landscapes will have to consider the interactions of abiotic and biotic ecosystem compartments with new qualities that can not be compared to historical conditions. Such scenarios have to take care of the individualistic properties of landscapes. Generalizations are dangerous within landscapes, but perhaps impossible across landscapes. Scenarios also have to integrate the uncertainty of future human values. This may lead to differing directions of the development under a given environment

It seems quite clear, that the questions and methods in landscape ecology show a vast diversity of approaches (see Chapter 1.4). Only a few of them are directed to the future. But today, the **prognosis** of future developments and resulting shifts in landscape patterns **becomes more and more impor-**

tant. Today, global, regional and local changes show an increasing speed. There are reasons to believe, that rapid environmental changes will take place; rapid compared to former developments. Such changes can affect ecosystems directly, as the change of land use patterns, and indirectly as well, as the change of biodiversity within persisting patterns. The loss of biodiversity, which is mainly due to the limited ability of species to adapt to new environmental conditions as fast as they are changing, will affect ecosystem functions as erosion control, nutrient cycling or biomass production and via such mechanisms also the stability and vulnerability of ecosystems and landscapes.

Simulating complex systems is obviously restricted by the information that is available about the mechanisms and the direction in which certain parameters will react. Under recent conditions, there can be no experience with environmental conditions and impacts that are expected to occur in the near future. This is mainly true for land use changes, where the data quality is uncertain (Brialssoulis 2001). This is a major argument, why different scenarios should be applied to simulate various site performances.

Powerful **tools** to calculate and to analyze future changes exist since computers and software offer the possibility to simulate developments of landscapes within a framework that did not yet exist before. The integration of modern approaches as remote sensing, GIS, and ecological modelling algorithms (see Chapters 6.2 to 6.4), can open new perspectives for the quality and precision of prognoses. Such techniques can contribute to a better understanding of today's spatio-temporal patterns and in consequence to precise simulations of changing environments.

4.3.2 Panta Rhei

The major problem in landscape prognosis is the projection of oncoming developments on the basis of the knowledge and the environmental conditions of today. It is to ask, which present-day landscape traits will react to landscape changes or even promote them. Models to predict future conditions of disturbance regimes or in the ecological background are based on data sets gained recently. It is not clear, whether this data quality is appropriate to calculate future situations. As we do not know, what will happen, the choice of parameters to integrate into a model is a difficult task.

There are also uncertainties about former conditions within landscapes. This is why landscape models have to be applied also in order to simulate historical landscapes. If it would be possible to verify the results of landscape models on the basis of **historical data** on landforms and vegetation, soils and water regime, it would be promising to apply such models to modern questions and problems. One field of research is the modeling of glaciers or sea level fluctuations, because these mechanisms have left historical traces (Figure 4.3-2).

Figure 4.3-2: Glaciers are a favorable object indicator to model past and future environmental changes: The Marmolada glacier (Dolomites, Italy) (Photo: O. Bastian 1998)

The changes of landscapes during their development have been effective on a variety of **spatial and temporal scales**. Today, most changes caused by human activities are very much faster than the changes, which have occurred in the past (see Chapter 4.1). The industrial and technical development, the freedom to travel, global market exchanges etc. contribute to this new temporal quality. The information society offers the access to new ideas and techniques within short time periods world wide.

Processes are no longer restricted to local or regional scales. The social and demographic trends, and, related to this, the economic and technical progress, are a motor of the development. The increasing human population density creates difficulties and political conflicts in developing countries. These problems will increase and promote land use changes. Industrial countries, on the other side will continue to produce and experience new pollutions and pollutants. The changes in the atmosphere will become a central question, and intensive efforts will be necessary to protect the environment.

Other qualities of environmental change are not as obviously negative or dangerous. The powerful vectors that connect continents today (ships, airplanes, etc.), are responsible for the exchange of organisms and diaspores. Some species are successful and can establish in a new environment. Some of these plants and animals develop aggressively in new habitats. When they become a threat to natural ecosystems, they are classified as "invaders" or **invasive species** (e.g. Cronk and Fuller 1995, Figure 4.3-3).

However, not the direct threat of species, but habitat loss is and will be the major reason for the **extinction of species**. If extinction happens as a singular event, only isolated populations will be concerned, but if certain biotope types such as traditionally used meadows and pastures within whole landscapes are abandoned or changed regularly this will affect the whole species pool of landscapes or regions

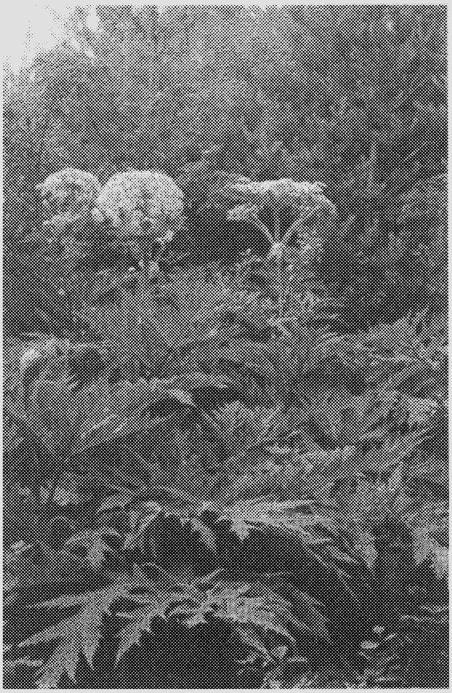

Figure 4.3-3: Heracleum mantegazzianum is an invasive plant species in Central Europe originating from Caucasus tall herb communities (Photo: O. Bastian 2000)

4.3.3 From local to global scale

Today, not only the velocity of change is high, perhaps even more striking is the spatial extension of environmental changes (see Chapter 4.1). Human impact is no longer restricted to the scale of an individual human being or to a tribe or village but to much larger areas. Landscapes are affected by impacts whose sources lay in some cases far outside of its own range. And conversely, it is common, that mechanisms taking place in a certain landscape, e.g. CO_2-production by the combustion of fossil energy or the setting free of NH_3^+ via agricultural manures, will affect **global processes**.

The release of compounds into the atmosphere, the modification of the ozone layer, the pollution of groundwater and the anthropogenic global warming reached new spatial and temporal qualities in environmental change, that were hard to imagine only some decades ago (e.g. Claussen and Cramer 1998).

Landscape ecology itself - and not only its objects - was very much influenced by the technical evolution of the 20^{th} century. Especially the broadening of the human horizon by aerial photographs was a key factor in the development of this discipline. Today satellite imagery allows world wide monitoring (see Chapter 4.2) of certain qualitative aspects of the earth's surface.

The scale of environmental change is largely related to the **vectors** that are responsible for the transport of matter, energy and information in ecosystems. On the one hand, qualitative and quantitative aspects of these three factors have changed or likely will change. On the other hand, vectors are changing as well. Connections between continents have been created via infrastructure and vehicles. In addition to that, the flow of information via communication devices as the internet creates a new speed and a new distribution of knowledge, which can be beneficial to mankind, but not necessarily has to be. The latter can become true, when possible consequences or the ranges of applicability of problematic techniques or methods are not yet clear.

4.3.4 Scenarios

How to predict landscape changes under new and only vaguely predictable conditions? One possibility would be a semantic description of scenarios or their graphical visualization. Here new possibilities in the processing and manipulation of photographs offer the tool to visualize oncoming landscape patterns. Expected landscapes can be modeled in GIS which helps, for instance, to simulate different combinations of site conditions and land use or the effects of fragmentation (see Chapters 2.3 and 7.3, Blaschke 1999).

As human decisions have a great influence on the development of landscapes, scenarios that integrate socio-economic rules and prerequisites will be an important tool in this context. Scenarios have to integrate ecological models (see Chapter 6.4). However, they have to consider that in the future, not only climate, soil conditions, water regime and biogeochemical cycles might have changed, but also human interests in natural services will have new qualities. We can ask from our current position which developments are desired, but the answers we will give today will be different from the answers that anyone would give some decades from now. This is a matter of fact, as **normative social values** always have changed during history.

This is perhaps the most problematic aspect within the prognosis of future landscapes. Perhaps we will succeed to model the development of soil nutrient availability, of precipitation regime and of other environmental aspects of landscapes in a certain time from now with a satisfying accuracy. And perhaps, which is more difficult, we will come close to predict, how species, communities and ecosystems interact. But, we have reasons to argue that it will be quite **impossible to model the oncoming social needs** and values that will presumably have a stronger effect on landscape ecological functions and performance than the environmental background.

As prognoses have to consider the direction of development of human societies, it will be necessary to take care of the various social and economic interests of people to identify the decisive mechanisms and the requirements for the future. However, scenarios can also be used to find out, which kind of landscape would be preferred. One method to apply scenarios is to produce virtual images of future landscapes and integrate them into an iterative process between landscape planning, stakeholders and decision makers (Tress and Tress 2001b, see Chapter 7.12).

4.3.5 Monitoring, experiments and models

The prognosis of future landscapes will be based on different techniques and data qualities. Methods will have to integrate monitoring, as well as experimental and modeling approaches. Data qualities will have to integrate biotic and abiotic components and first of all be able to indicate complex within-landscape interactions.

Although we are equipped with a variety of techniques to investigate landscapes, many of these will not be appropriate to forecast future developments. New methods to document for instance the effects of global warming or of changes in ultraviolet radiation have to be developed. This applies also for biodiversity loss, soil erosion, groundwater levels and many other ecological qualities and processes. Only few modern approaches really offer quantitative data at the landscape level.

To monitor such changes and to **identify the effects of changes** in overall site conditions is an important task (see Chapter 4.2). It will not be satisfying to document these changes alone. We realize that we cannot wait until landscape changes occur and perhaps restrict the quality of life or cut down resource availability and land use capacity. Advices and guidelines are needed to avoid or to reduce detrimental effects of global and regional changes to ecosystems and resources.

According to **global warming** some new research projects (e.g. Pauli et al. 1999) aim at a monitoring of ecological reactions. Long-term research has to be installed to address such mechanisms (see Chapter 4.2). The observation of the successive change of vegetation is one important approach in this field. The problem is to assure, that the target parameters are mainly driven by climate change and do not interfere with other site conditions.

Generally, we will have to apply approaches that integrate different techniques and methods. To cope with the new questions and tasks, it seems to be promising to develop a methodological design that combines monitoring, experiments and models (Figure 4.3-4). The **integration of various methods** into a methodological framework that refers to a general theory and concept and has clarified the questions and problems to deal with, can contribute to solve these problems within a reasonable time.

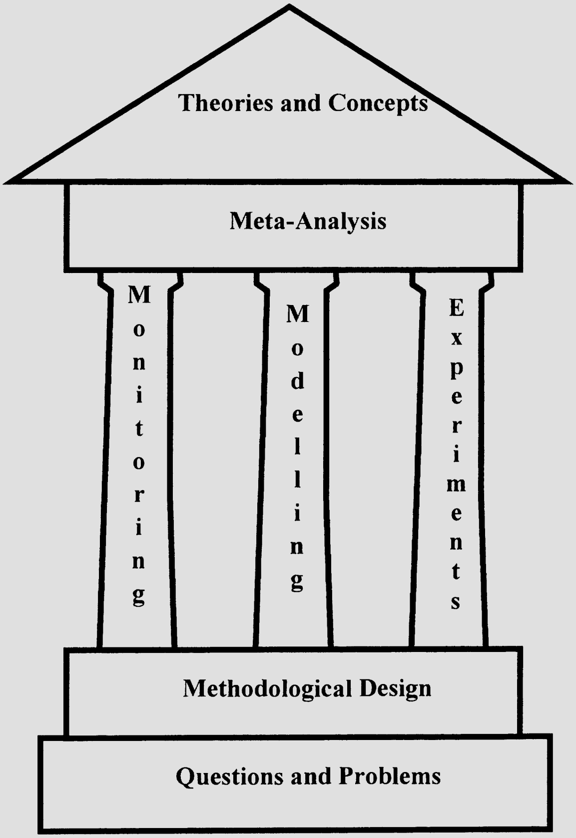

Figure 4.3-2: The methodological temple of landscape prognosis. The environmental questions and problems can only be solved under the roof of a sound theory. Concepts and theoretical background work has to be done before applying analytical techniques. On this basis a methodological design can be established, that responds to the original questions and is valid only under a certain theory. According to the prognosis of future developments, the building will be more stable, if one takes different methodological approaches into account, that relate to each other. However, first of all, these methods should be subject to a final meta-analysis, that integrates the specific results.

Within this combination of methods, the simulation of future landscape conditions on the basis of **mathematical models** is perhaps most convincing (e.g. He et al. 1999, see Chapter 6.4). Such models however are based on processes and objects which occur today under recent environmental conditions and land use. They have to be modified and integrated into a new environmental frame. This is also true in restoration ecology, where complex models will help to design management techniques (see Chapter 7.11). In nature conservation, ecological models can contribute to design habitats and reserves for endangered species.

In addition to monitoring and modeling, the application of **experimental approaches** is necessary as well. Under controlled conditions, but close to the real conditions in ecosystems, model ecosystems could be installed, to mimic site conditions that are expected to occur. At the landscape level, it will be difficult to simulate certain expected environmental conditions. However, for fragmentation or homogenization, or for the loss of biodiversity by introducing monocultures, experiments can be thought of at this level (e.g. Pither and Taylor 1998). Perhaps more important, experiments at the level of communities and ecosystems will offer the possibility to investigate the consequences of environmental change and of the loss of biodiversity (Hector et al. 1999). Model communities that are close to natural conditions can deliver insights in the functioning of ecosystems.

Finally, we have to ask: Do we have good ideas, which developments are likely to occur? Which circumstances have to be considered? What will really dominate the future environmental discussions? Will it be the global change of temperature, the increasing precipitation, the rise of the sea level, the Gulf Stream, the increasing thunderstorms and hurricanes, the land use change in tropical and subtropical regions, the technical development, the societal needs, and the population growth? One thing is sure: **there will be surprises!**

Chapter 5

Landscape assessment

O. Bastian, B.C. Meyer, E. Panse, M. Röder, R.-U. Syrbe

5.1 Ecological carrying capacity and stability

5.1.1 Carrying capacity, ecological footprint, loads

Ecological carrying capacity is a quite abstract term. In landscape terms, it describes the ratio between the possible demand and the maximum load within the context of ecosystem stability. This term is used in many ways (Dhont 1988). Therefore, its methodological discussion requires precise clarification of its meanings; otherwise it remains an empty political formula.

Engineering sciences understand "carrying capacity" just as a measure of stability, meaning the degree of load a system can cope without impairment or if it is exceeded the operability of the system is threatened. Malthus (1798), the term was applied later in a geographical context, as the maximum possible density of a population within a limited territory, that could maintain a permanent (agrarian) self-sufficiency (Döhrmann 1968, Penck 1925, Scharlau 1953). The carrying capacity became a theoretical and variable feature. It depends very strongly on the technology and on the life style of the respective people. Because of its misuse during World War II (justification of annexations), this approach is used today less frequently or it is referred to the earth as a whole (Daily and Ehrlich 1996, Waggoner 1996).

Economic carrying capacity refers to the suitability of a region to tolerate immigration on the basis of the relation between workers and employment. Planning and economics describe the demand necessary for the economic success of an investment with this term. Also a combination with the

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adjective **ecological** can cause misunderstandings, because in ecology carrying capacity is defined as the "max. population of a given species that can be supported indefinitely in a defined habitat without permanently impairing the productivity of that habitat" (Rees 1996).

Since the Rio de Janeiro 1992 Conference, the idea of carrying capacity has received a boost as an instrument for the investigation of sustainable land use, and, through this, new facets became obvious. A crucial problem is, that the **natural carrying capacity** given by the limited efficiency of ecosystems, can be exceeded considerably within a certain area and time period. This is associated with either consumption of (itself not regenerating) potential resources or via stress of other territories, so-called **appropriated carrying capacity** (Siedentop 1997).

The **ecological footprint** was introduced into this context by Rees (1992). This term (in effect, the inverse of carrying capacity) represents "the corresponding area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on earth that land may be located" (Rees 1996). The ecological problems, resulting from the associated over-exploitation, are frequently shifted to foreign territories, supported by global market mechanisms. Although there are naturally poor as well as rich ecosystems (Haber 1992), the spatial division of labor represents a prerequisite for the cultural development of humans. One can understand the appropriation of carrying capacity on a global level as a modern (environmental) form of colonialism, because it limits the possibilities of development for the non-industrialized countries.

In landscape ecology, the problem of carrying capacity is often equated with the treatment of **critical loads** and **critical levels** (Hettelingh et al. 1991, Lenz 1994, Nagel and Gregor 1999, United Nations 1993). The goal is to identify such concentrations of e.g. air pollution and released deposition rates, whereby the ecosystems concerned are able to absorb them by buffering or regenerating themselves without irreversible changes. This approach was successful in keeping the clean-air policy. However, it has a very narrow focus, because among other things non-chemical aspects can hardly be included here. Investigations of an extended ecological carrying capacity should enter the existing maximum stress of the ecological systems and exceed area-density ratios. A possible **definition of ecological carrying capacity** reads: E. c. c. indicates the maximum admissible use of ecosystems in their landscape, whereby preservation or reproduction of the basic conditions necessary for it is secured on a long-term basis.

This implies a fixed tolerance (Bastian and Schreiber 1999) concerning a certain use or several connected use-activities in a landscape. The limiting criterion is that the prerequisites for the use are not endangered, which depends on the sensitivity of the ecosystems concerned (Figure 5.1-1). A long-term effect is produced particularly if the impairments released by the use activities outlast available recovery phases. It is not meaningful in this context, to characterize solely consumption of non-renewable goods (e.g. consumption of fossil fuels, surface sealing) with carrying capacity. Such a treatment must be integrated into a more complex landscape, buffering the intensively used areas.

Figure 5.1-1: By frequent driving on sensitive unpaved Mongolian steppe tracks, the carrying capacity is exceeded. Thus the erosion of the unstable river bank is increased (Photo: O. Bastian 1997)

The first **main parameter of carrying capacity** is the **maximum load** on ecosystems by use-conditioned impacts on the environment. The latter depends on the ecological conditions, whereas different possible (quantitative) intensities can be designated, according to the (qualitative) type and the time performance of uses. Since very often several use activities require the same environmental factors, side effects and amplifier effects must be considered in the context of the "use network" (Eberlei 1985) defined by it. Political priorities play a crucial role concerning overlap in use. Also the ecological maximum load is not objective, particularly since "unfavorable" effects are included. It represents a certain aspect of the natural carrying capacity, whereby safety and tolerance considerations are not included.

As second parameter the "basic conditions" for a certain use are to be considered. This component of carrying capacity is not to be determined objectively alone. Rather politically set "basic conditions" (in the sense of limit values, or ideas of landscape development) can be integrated into this point. The carrying capacity, discussed here, refers to the landscape as an entity and therefore it requires a complex approach.

Finally it is very important, to what extent the basic conditions of use may be considered as "secured" (see definition). There, questions of the ecological risk analysis or the definition of a sufficient "safety level" (as with technical applications) play the main role.

5.1.2 Sensitivity, disturbances, and stability

The term **sensitivity** is also used in a different manner (see Chapter 7.4.6). In biological and technical literature, it is understood as objective and thus value-free. It characterizes the ability of a system to respond after an influence by self-change, and similarly to indicate such an effect. Sensitivity does not refer usually to the landscape as a whole, but to certain partial aspects (ecosystems, populations, resources, functions or individual landscape features), which may have different sensitivities. Furthermore, it is meaningful to differentiate the type and intensity of the disturbances, which can produce appropriate violations.

In particular, environmental law and planning use this term in the sense of **vulnerability** of "sensitive areas", i.e. also under the criterion of depreciation in the case of damage. Such an application is connected inevitably with the aspects of value. In the sense of terminological clarity it is therefore more exact to use "vulnerability" instead of "sensitivity".

Disturbance, used as a value-free term, includes both critical developments within an ecosystem and effects from outside, which exceed the type or range of regular variations. It is crucial whether the ecosystem or living species therein can adapt to these changes. Irregular or abrupt effects (like those usually caused by human activities) possess, therefore, a very high disturbance potential. If such an effect results by conscious human actions, it is called more precisely an "intervention".

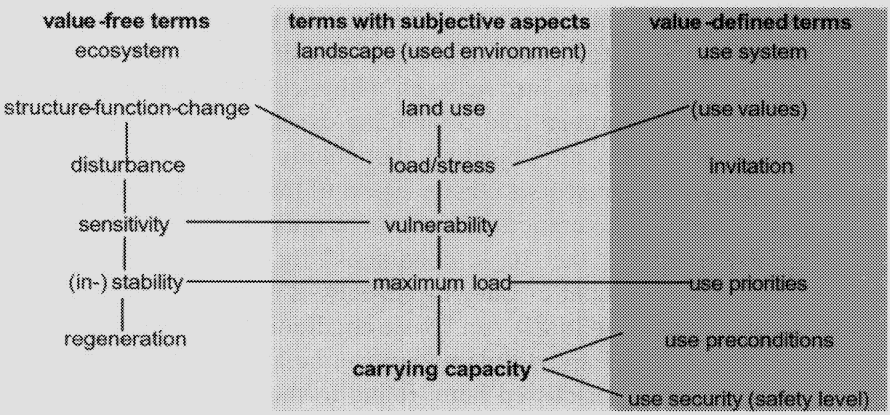


Figure 5.1-2: Systematic of the terms explained

The ability of ecosystems to resist disturbances is described in landscape ecology by the term **stability**. An initial differentiation of ecological stability can be made with respect to disturbance, in particular its type (natural or human-made), origin (endogenous or exogenous), duration (persistence), intensity, or frequency necessary for significant modifications (Table 5.1-1, Figures 5.1-2 to 5.1-4).

Figure 5.1-3: Spruce monocultures are, as a rule, unstable with regard to pests and air pollution: Damaged mountain spruce forests (Erzgebirge mountains, Saxony, Germany) (Photo: O. Bastian 1985)

Figure 5.1-4: Bogs are more or less stable, however they are sensitive to human impacts/ disturbances, e.g. drainage: The Dubring moor (Upper Lusatian Lowland, Saxony, Germany) (Photo: O. Bastian 1984)

Table 5.1-1: Basic types of ecological stability (Bastian 1999b following Gigon 1984)

	dynamic behavior of the ecosystem	without external disturbances	with external disturbances
stability	none or very small variations	constant stability	resistance
meta-stability	regular variations	cyclic stability	elasticity
	irregular variations	endogene fluctuation	exogene fluctuation
instability	irreversible, strong changes	endogene change	exogene change

Further subdivisions are possible with regard to the reactive behavior of the system concerned. In relation to external disturbances, it is possible to differentiate an intrinsic, system-dependent ruggedness **occurring without modifications**, the so-called **resistance**, and the regenerative power of the system **after disturbance,** its **elasticity**. The idea of **metastability** (Forman and Godron 1986), developed on this basis, attained great importance because of their complex approach. The fact that ecosystems combine both resistance (physical system-stability) and regenerative power (elasticity) is embodied in the concept of metastability, which also encompasses the sense of ecological self-regulation. Dynamic ecosystems sometimes do not have very high physical system stability. But the loss of resistance by regular or moderate disturbances is often connected with an acceleration of regenerative functions and an increase in species diversity, adapted to changing and edge conditions. Therefore, predominantly natural and diverse ecosystems with a large amount of biomass are metastable.

Regarding the differentiation between value-free terms like stability and with-value aspects (maximum load in this case), it is not meaningful to divide stability according to ecological or anthropocentric points of view.

5.1.3 Methodology

Investigation of stability, disturbance regimes, and sensitivity is the province of the natural sciences. Therefore it can be performed with relevant landscape ecological procedures. With regard to carrying capacity and maximum load, however, evaluations and thus political specifications are also necessary, which scientists cannot provide alone. It is particularly problematic that in our (multifunctional) landscapes the effects of different uses must be considered, because usually the same resources or landscape functions are utilized in a multiple manner (Neef 1972). Such a holistic approach (see Chapter 1.3) requires time-consuming complex investigation, and it has not been successfully implemented yet. For simplification one tries to reduce the complexity in an appropriate way and to consider the uncertainty of unquantifiable amplifier and side effects by determined minimum values and tolerance limits (which usually are not scientifically derivable).

For the **differentiation of disturbance and "normal" variations** not only the degree of the ecological modifications, but also their spatial and temporal distribution can be decisive (White et al. 2001). An analysis (particularly with ecological monitoring, see Chapter 4.2) of the temporal behavior of disturbance regimes, including the released adaptation processes, is necessary. The results are needed partly for the following methods.

A prerequisite for the **determination of sensitivity** is to select the landscape components and features concerned, and the disturbances, which can influence them. The degree of sensitivity is determined through

– the exposure in relation to the disturbances (which must be determined beforehand), and
– the variability and adaptability of the subsystems concerned to the respective disturbance.

Sensitivity must therefore be determined "disturbance-specifically", as well as being time-dependent (because of the duration of the adjustment mechanisms). A possible methodology can be the following sequence of working steps:

1. definition of possible disturbances,
2. fixing of the considered time horizon (if possible according to the characteristic disturbance interval),
3. determination of the exposure in relation to the disturbances,
4. a) determination of the stability behavior for a class of disturbances,
   b) estimation of the recovery ability within the determined time interval,
   c) prognosis of the modification of the whole landscape, and
5. condensed evaluation of the sensitivity, e.g. as an effect function or by the specification of characteristic sensitivity levels.

If **vulnerability** has to be determined, first particularly "valuable" landscape features (with high functional performance or suitability) should be selected, which limits the data range of the following analysis. The condensed evaluation can be based then on a comparison of the potential (without considering influences from utilization) and the actual landscape functions including utilization.

The (ecological) **maximum load** differentiates itself on the basis of use-induced effects on the individual landscape components (so-called "effect factors"). On the basis of the relevant types of use and the technologies connected with them, the most important effecting factors, as well as their intensity, are determined. The following analysis of the spatial and temporal behavior of the (land) use activities and their effecting factors should give detailed information on side effects and amplifier effects relevant to those other uses which utilize the same landscape functions. From the "load profile", compiled in such a way, the associated disturbances and their intensities are derived. The load of the landscape features concerned can be measured in comparison with the vulnerability. Landscape planning has developed a methodology, called **ecological effect analysis,** to determine ecological side effects of land uses with each other and with nature. In practice, this methodology is applied using, in particular, check lists, effect chains, sensitivity matrices, conflict matrices and diagrams (Bierhals et al. 1974, Krause and Henke 1980).

A condensed maximum-load-evaluation of the landscape can be done via aggregation of individual load levels on the assumption of a balanced relation of disturbance and vulnerability. Both parameters, however, are afflicted with large uncertainties and no comparison yardsticks for quantification are available. Recommended methodologies are either the so-called **ecological risk analysis** (Bachfischer et al. 1977, Geier 1981, Schemel 1978, Scholles 1997) or area balances (like the ecological footprint determination), but time balances (use period in comparison to recovery time) are also usable. In particular, the ecological risk analysis, developed for practical planning, also applies normative items, in order to master the uncertainty of ecological information.

"Although carrying capacity evaluations under ecological criteria are possible regarding the intensity of individual uses, the derivation of carrying capacity must take place, however, on a basis of the use network in its dependency on the common natural resources", wrote Eberlei (1985). He developed a very extensive methodology to determine **carrying capacity** by a holistic approach. This methodology was separated into three levels:

- basic level, considering the natural resources,
- function level, indicating the use potential, and
- action level, regarding the use effect relations.

It considers all relevant relations and parameters gradually for each landscape item concerned on the basis of matrices of spatial and temporal overlap. On the conditions of different uses he particularly emphasized cumulating amplifier effects, which were subdivided into "simultaneous effects" and "development effects".

Because of often indistinct data and incomplete knowledge about the ecological system, the introduction of a "safety factor" is necessary. A simplification of the methodology is enabled, if this introduced safety factor is extended to include the uncertain socio-economic criteria, varying the maximum load. In individual cases, a value below the maximum load (50% and less, if quantifiably) becomes necessary, while a limited overload

(>100%, i.e. acquired carrying capacity) could be tolerated elsewhere in the sense of the spatial division of labor or area dedication.

Such a simplified methodology consists of the following steps:

1. search of the existing or the planned uses and determination of the spatially differentiated disturbance potential, starting by considering amplifier effects (map or matrix),
2. estimation of the sensitivity or vulnerability of the landscape features concerned regarding the existing disturbances (effect factors),
3. comparison (and aggregation) of the intermediate results, and derivation of load level and maximum load of ecosystem,
4. definition (on the basis of political specifications, ideas of landscape development or ecological risk analyses) of spatially differentiated tolerance limits for the load with different effect factors, and
5. checking whether existing uses or those which can be expected exceed or fall below these tolerances and partitioning into carrying or not carrying versions (use intensities, mosaics, technologies) on the basis of complex use pattern in the landscape.

5.2 Landscape functions and natural potentials

5.2.1 Definitions and theoretical fundamentals

With regard to the practical application of landscape ecology, e.g. in land use, management and nature conservation, the concepts of landscape functions and natural potentials prove helpful approaches to analyze and to assess landscape, especially from a human point of view. Potentials and functions characterize the capability and usability of a landscape (concerning human needs, demands and goals) in a broad sense. That means that particular emphasis is given to the fact that so-called ecological functions are included, too. Usually, such aspects as a landscape's suitability for manifold human demands, risks emerging from land use practices or from natural disasters, but also the role of landscape for human well-being (landscape beauty, micro-climatic effects and threats) are related to the anthropocentric point of view. The importance of landscape for the balance of nature (landscape stability, ability to buffer disturbances, functioning of matter and energy flows, biodiversity), however, are assigned to the landscape ecological or the natural perspective. The sense of such classifications is not very distinctive, because biodiversity, natural balance, ecological functions and nature all are an indispensable precondition of humans' existence as biological and social creatures.

The term **potential** was introduced to landscape research by the German geographer Ernst Neef in the sixties (Neef 1966, 1969). He defined a complex "gebietswirtschaftliches Potential". In this manner, the interpretation of landscape attributes for human purposes (utilization), however, was not easy to realize. The idea of reducing landscape characteristics (nature) and human rates of output (society) to a common denominator (i.e. the immediate linking of physical, chemical and biological processes with socio-economic processes and phenomena, e.g. in the form of energy quantums) was widespread during that time (Iaatinen and Cunningham 1975, Voraček 1971), but it was not a conclusive approach for practical solutions (Mannsfeld 2000a). Therefore, it was necessary to operationalize this concept. Land use categories, as well as spatial planning, need a differentiation of the complex entities of nature and landscape. Only this made possible the comparison and assessment of natural conditions and their impact on human influences, with regard to decision-making. Apart from previous works (Langer 1970b, Kopp 1975), Graf (1980), Haase (1978), Mannsfeld (1979) and in particular dealt with this concept. Haase (1978) distinguished several specific, so-called **partial natural potentials**: biotic yield potential, water supply potential, waste disposal potential, biotic regulation potential, geoenergetic potential and recreation potential. During the following years, the concept of natural potentials was developed further and applied in landscape ecology and planning e.g. by Dollinger (1988), Durwen (1995), Haase et al. (1991), Hrabowski (1978), Kopp et al. (1982), Lüttig (1983), Mannsfeld (1979, 2000) and Marks et al. (1992). **Natural potentials** characterize the totality of landscape attributes with regard to a possible utilization by human society. In reality, it is a matter of **natural resources** (Graf 1980, Haase 1978).

For the **assessment**, natural potentials, human demands and specific goals are compared with the concrete natural conditions in order to grasp landscape performance in categories like availability, carrying capacity and usability. Mannsfeld (1983) proposed an algorithm including the choice of indicators and their assessment, as well as the determination of ranks of landscape units in their suitability for special natural potentials. The comparison of potentials enables statements concerning multipurpose use and possible land use conflicts. The assessment of natural potentials is an important step in converting parameters (knowledge) from natural sciences into socio-political categories, from sciences into practice and from ecology into planning, which was defined by Neef (1966) as the "transformation problem" (see Chapter 5.3.1).

In parallel with the concept of natural potentials, the term **landscape functions** became established for the performance of a landscape in the broadest sense. The term "function" has particular meanings in mathematics and politics, but could also have in landscape ecology (functions in the sense of processes and fluxes of matter). De Groot (1992) defined landscape functions as the capacity of natural processes and components to provide goods and performances which satisfy human demands directly or indirectly. According to Haase (1985), the assessment of social functions of a landscape is a pre-condition of relating the actual landscape state to economic categories and processes. There is, however, much terminological confusion. The terms "potential" and "function" are often applied synonymously, although - strictly speaking - this is not justified.

There have been a lot of attempts to **classify** the almost confusing variety of **landscape functions**. Important criteria are (Lahaye et al. 1979):

- kind and content of human needs and preferences (values) which are related to the specific function,
- kind of product or performance being supplied,
- kind of landscape factors (abiotic, biotic), which are characterizing the function concerned, and
- the sphere of effectivity.

"External functions" satisfy human demands directly, whereas "internal functions" are more related to the landscape system itself. Other authors distinguish between "natural functions" on the one side, and "societal functions" on the other side (Niemann 1977, 1982, Preobraženskij et al. 1980, van der Maarel and Dauvellier 1978). A strict differentiation is problematic, since the "internal" functions are a pre-condition for the "external" ones, and the health and functionality of the natural balance is also desired by the human society. One must not forget the connection and interference of different landscape functions, their interdependence and causality. Nevertheless, a classification of landscape functions is sensible (Table 5.2-1).

Niemann (1977) distinguished functions of production, landscape management, human-ecology and ethics/aesthetics. Another classification includes regulation, carrier, production and information functions (De Groot 1992, De Groot et al. 2001, van der Maarel 1978). The relationships and conflicts between economy and ecology are especially emphasized by the division into economic (production), ecological (landscape management) and social functions (Bastian 1991b). Kontriš (1978) expressed "social" with "cultural" and "conducive to health"/"recreational". Haber (1979b) identified production and landscape management functions, which are related to so-called production and protective ecosystems. In forestry, the term "comitativ" is usual for all effects going beyond forest timber production and which include a forest's influences on landscape balance and development as well as on humans' physical living conditions and creation of awareness (Thomasius 1978). Landscape functions can be arranged hierarchically into several distinct levels: groups of functions (1st order functions, e.g. ecological functions), main functions (2nd order functions, e.g. regulation of populations and biocoenoses), subfunctions (3rd order functions, e.g. habitat function).

Table 5.2-1: Classification of important landscape functions (from Bastian 1998b, 1999a)

Groups of functions
- functions of 1st order
- functions of 2nd order (main functions)
- functions of 3rd order (subfunctions)
A – production (economic) functions
- availability of renewable resources
- production of biomass (suitability for cultivation)
plant biomass
- arable fields (husbandry)
- permanent grassland
- special crops (e.g. fruit-culture)
- wood (forestry)
animal biomass
- game (hunting)
- fish (fishing, pisciculture)
- water accumulation
- surface waters
- ground water
- availability of non-renewable resources
- mineral raw materials, building materials
- fossil fuels
B – ecological functions
- regulation of matter and energy flows
- pedological functions (soil)
- resistance to erosion/ to compaction
- resistance to underground wetness/ to drying out
- decomposition of harmful matters (filtering, buffering and transforming functions)
- hydrological functions (water)
- groundwater recharge
- water storage/ run-off balance
- self-purifying power of surface waters
- meteorological functions (climate/air)
- temperature balance
- enhancing of atmospheric humidity
- influencing of wind
- regulation and regeneration of populations and communities (of plants and animals)
- biotic reproduction and regeneration (self-renewal and maintenance) of biocoenoses
- regulation of organism populations (e.g. pests)
- conservation of the gene pools
C – social functions
- psychological functions
- aesthetical functions (scenery)
- ethical functions (gene pools, cultural heritage)
- information functions
- functions for science and education
- (bio-)indication of environmental condition
- human-ecological functions
- bioclimatological (-meteorological) effects
- filtering and buffering functions (chemical effects - soil/water/air)
- acoustic effects (noise control)
- functions of recreation (as a complex of psychological and human-ecological effects)

5.2.2 Possible assessment procedures

In the meantime, there is an almost unmanageable multiplicity of relevant papers concerning methods and approaches for assessment of natural potentials and landscape functions. At this point, only principles and selected examples can be mentioned. These methods must be adaptable to specific purposes - i.e. their objectives, dimensions, precision, available data, time and labor. There is also no room to give detailed descriptions of assessment procedures, especially of the parameter weighting and combining.

Usually, natural potentials and landscape functions are shaped by numerous parameters. There is a conflict between the scientifically-based demands of a holistic and therefore mostly complicated assessment procedure on the one side, and the tendency of simplification for practical purposes, e.g. in landscape planning and environmental impact assessment, on the other side.

In order to assess landscape functions, essential attributes (key factors, indicators) must be chosen which both allow clear and exact statements and are economic to obtain. According to the particular landscape function and the applied approach (method), attributes of the geocomponents like geological structure, relief, soil, water, climate, bios and land use should be involved (Table 5.2-2).

For the assessment of landscape functions, mainly semi-quantitative methods are still used. The reasons are: the shortage of precise, quantitative analytical data, and the better applicability to practical purposes of the wide, comprehensive landscape planning. However, recently a trend to quantification has become conspicuous.

Generally, the assessment of landscape functions is possible in different ways. Therefore, no universally applicable method can be offered, but only principles and examples for the assessment of single functions. The **choice of methods** depends on the aim of the assessment, on scales and spatial peculiarities, and on available data. That is why, the following examples can only give a rough indication of possible assessment procedures for selected landscape functions.

Subsequently, we focus on those landscape functions/natural potentials, which are considered normally in many landscape ecological studies and in the practice of landscape planning. :

- (potential) **biotic productivity**: ability of a landscape to produce biomass by photosynthesis in a sustainable manner (biotic yield potential according to Haase 1978),
- **resistance to soil erosion**: ability to withstand soil losses caused by human activities, which exceed normal (natural) amounts (e.g. by limits of mineralization processes, bedrock weathering),

- **water retention capacity** (runoff regulation function): ability of a landscape to contribute to balanced water runoff situations and to retain the water (e.g. prevent extreme flooding) by the reduction of fast runoff components (surface runoff, interflow),
- **groundwater recharge**: flow of percolating water to the groundwater,
- **groundwater protection**: the different ability of a landscape to protect groundwater from contaminants, to weaken their effects or to delay their penetration,
- **habitat function**: the landscape's ability to supply favorable living conditions for a rich flora and fauna (with its biocoenoses and biotopes),
- **potential for recreation** (in the landscape): the landscape's capability to realize material and esthetic qualities for human recreation, i.e. the relaxation, recreation, health, and enjoyment of the landscape in order to elevate fitness, joy and life-span, and thus to satisfy cultural and esthetic requirements of the society (Haase 1978).

The assessment methodologies for the **biotic yield potential** can be subdivided into biotic and non-biotic approaches. Biotic approaches are based on site specific biomass production, either on the net primary production (of the potential natural vegetation, see Hofmann 1988) or - directly - on the actual yield of the crops. The disadvantage of the last-mentioned approach is the dependence of biomass production on fertilizers and other anthropogenic nutrients, especially in industrial countries.

The non-biotic methods use several parameters of geocomponents. A typical approach of this group is the so-called soil fertility, referring to soil parameters only, applied, for example, by the German Soil Inventory for taxation (see Chapter 3.2.3). Another method was elaborated by Klink and Glawion (in Marks et al. 1992). It follows the principle of limiting factors, i.e. the most unfavorable parameter is decisive. Parameters of relief, soil, water balance and climate influencing land use form, yield and costs of production, as well as endangering the performance of the site by soil erosion, frost and flooding, are included in this. The suitability for agriculture, independent of the particular actual land use can be evaluated. A provisional assessment can be obtained by considering groundwater level and soil texture (size of soil particles), nutrient supply, amount of stones and humus, depth of soil, soil moisture, and field-moisture capacity. By including the relief (hill slope) and climatic factors (average annual temperature and precipitation, danger of frost, erosion and flooding), the final result is achieved.

Table 5.2-2: Landscape characteristics (parameters) which are often necessary for the assessment of landscape functions (and natural potentials) in landscape diagnoses (from Bastian 1999a, Bastian and Röder 1998)

parameters	**landscape functions/natural potentials**													
	y(s)		y(e)		p		a		r		b		re	
scale (dimension): m - meso, s - small scale														
	m	s	m	s	m	s	m	s	m	s	m	s	m	s
geological basis					(x)		(x)		(x)		(x)	(x)		
relief														
- slope	x	(x)	x	(x)			x			x			x	(x)
- altit. differences													x	
- small structures													x	x
soil														
- substrate peculiarit.	x	x	x	x	x	x	x	x	x	x	(x)	(x)		
- main soil forms	x				x		x		x	x				
- soil forms		x		x		x		x		x				
water														
- surface waters									(x)	(x)	x	x	x	x
- groundwater table/soil water balance	x	(x)			x	x	x		x	x	(x)	(x)		
climate														
- annual precip.	x		x				x							
- monthly precip.		x					(x)							
- monthly evapor.							x							
- annual temperature	x													
- occurrence of frost	x													
biota														
- biotope types											(x)	x		x
- vegetation units		(x)										x		(x)
- habitat structures												x		
- species									x		x	x		(x)
- spatial parameters											(x)	x		
- pot. nat. vegetation	(x)	(x)									x	x		
land use														
- land use types		x	x	x	x	x	x	x	x	x	x	x	x	x
- landscape elements			(x)	x					x	x		x	(x)	x
- specific data (surface sealing, irrigation/drainage, crop rotation, fertilizers)		x				x	x			(x)		(x)		

y - biotic yield potential (s - suitability, e - sensitivity: water erosion),
p - groundwater protection
a - groundwater recharge
r - regulation of surface run-off
b - biotic regulation potential (habitat function)
re - recreational potential

Soil erosion is defined as the loss of soil, especially as a result of human impact, since human-caused erosion can exceed that by natural causes many times (Figure 5.2-1). Soil erosion by water is one of the best investigated landscape ecological problems (in contrast to erosion by wind). It depends on erosion susceptibility of sites and erosive action of rainfall. Erosion susceptibility of sites depends on soil parameters (e.g. texture, content of humus and stones, humidity, infiltration capacity), relief parameters (e.g. hill slope and length) and soil cover (plants, land use etc.). Its evaluation is relatively reliable.

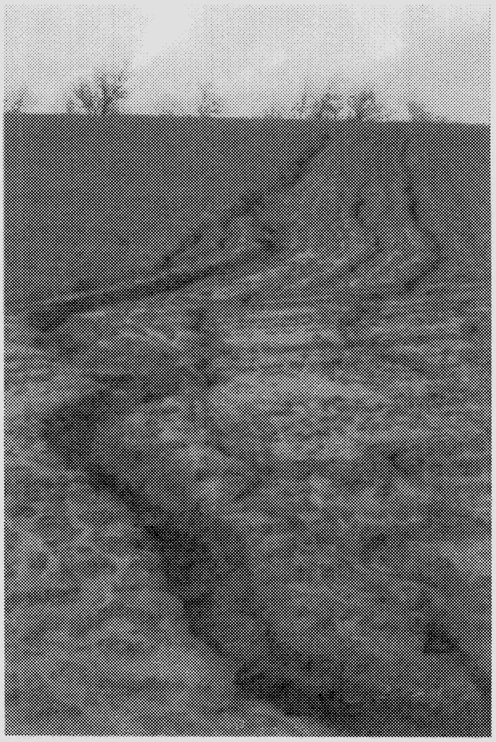


Figure 5.2-1: The resistance of loess soils to soil erosion by water is low. Heavy erosion damages in the Central Saxonian loess region (Germany) (Photo: O. Bastian 2000)

Most of the empirical assessment procedures are based on the **Universal Soil Loss Equation (USLE)** by Wischmeier and Smith (1978) and several specifications (e.g. Schwertmann et al. 1981). They enable a quantitative determination of soil erosion. The USLE defines soil loss as a product of indices of rainfall erosivity, soil erosivity, slope length, slope inclination, soil cover and erosion preventing measures. Because of its empirical character there is a need to validate USLE in different regions. Modeling erosivity of rainfall and the estimation of soil cover are especially difficult. The rainfall erosivity index is composed of the impact energy to soil surface (R-factor) and the maximum 30-minute intensity of the rainfall event (El_{30}). The universal validity of the EI_{30}-index, although applied world-wide, is nevertheless regarded as insufficiently close to reality. So are all the other rainfall erosivity indices founded on the same or similar bases (Seuffert et al. 1999).

One of the various methods, using medium spatial erosivity indices (and which can be recommended in spite of the problems mentioned above), is published by Schmidt (in Marks et al. 1992). The advantages of this method are the usually good availability of data and the simple assessment procedure which allow its application in landscape ecological planning processes, (Figure 5.2-2).

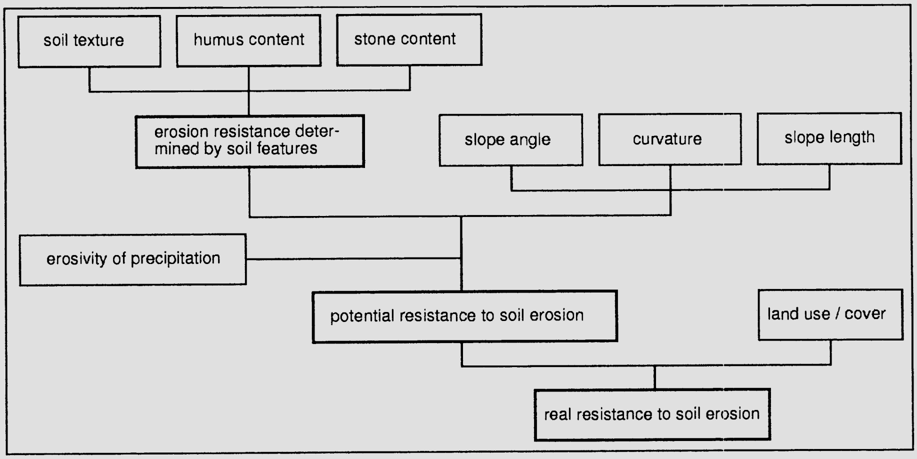


Figure 5.2-2: The assessment of soil resistance to water erosion (according to Schmidt in Marks et al. 1992, modified)

Recently, more physically based computer-supported **simulation models** have been developed such as the model EROSION 2D/3D by Schmidt (1996), which is practicable for small areas (see Chapter 6.4.4). The disadvantages of former physical models, such as the enormous number of parameters and the complicated handling, are partly overcome. The problems of quantifying erosion for larger areas will be solved soon.

Water retention capacity (or **runoff regulation** function) can be assessed in several ways. If catchment areas are the basis for evaluation and stream gaugings are available, discharge hydrograph analyses are preferred because of ensured and precise quantitative methods. In particular continuous discharge analyses allow detailed separation of discharge components (slow and fast base flow, interflow, surface runoff) and its residence time in the catchment area. Thus, it is possible to estimate and compare the flood danger of different basins. Another way is to model the relations between precipitation and runoff (e.g. Becker and Pfützner 1987) for river basins.

It is complicated to quantify site-specific water retention capacity, but is possible by measurements and modeling the respective water balance. Large areas cannot be calculated by these methods favorably, because of the immense expenditure. Nevertheless, site-specific knowledge about water retention is important to plan local flood-prevention measures. For this task empirical methods are much more suitable e.g. by Zepp in Marks et al. (1992, Figure 5.2-3).

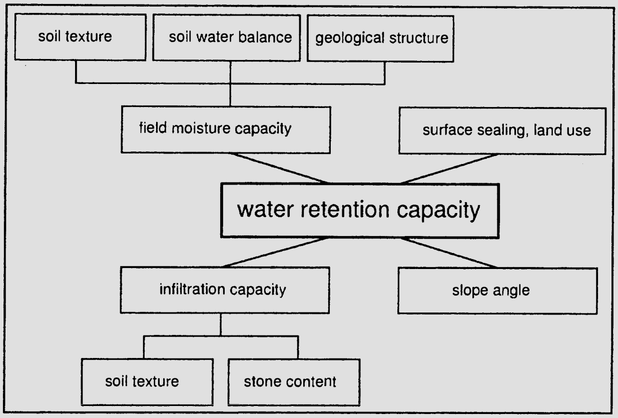


Figure 5.2-3: The assessment of water retention capacity (according to Zepp in Marks et al. 1992, modified). The values of each parameters are summarized to the total water retention capacity (five half-quantitative degrees)

Groundwater recharge is known to be the process of filling up the groundwater resources by infiltrated water. The knowledge about its regional and local differentiation is important for groundwater abstraction and protection. For example, areas with a high rate of groundwater recharge should not be exposed to harmful chemicals from industry or agriculture.

The groundwater recharge can be **measured** by lysimeters and tracers, and **evaluated** by discharge analyses, e.g. a low water hydrograph by Wundt (1958) and data of groundwater management can be **calculated** with the help of the water balance equation. The related methods are useful for particular scales only (points, river basins, small or large areas). For differentiated analyses in sedimentary rock areas without an essential direct runoff, the calculation by the water balance equation is recommended. In hilly and mountain areas, the quantity of interflow and surface runoff additionally requires consideration (Figure 5.2-4): At first, the site-related total runoff is calculated as the difference between precipitation and real evaporation. In hilly and mountain regions this total runoff consists of groundwater recharge, interflow and surface runoff. In a final step, groundwater recharge must be separated from the other runoff components. The results should be scaled. Thus, it is possible to produce detailed and relatively reliable maps of the groundwater recharge.

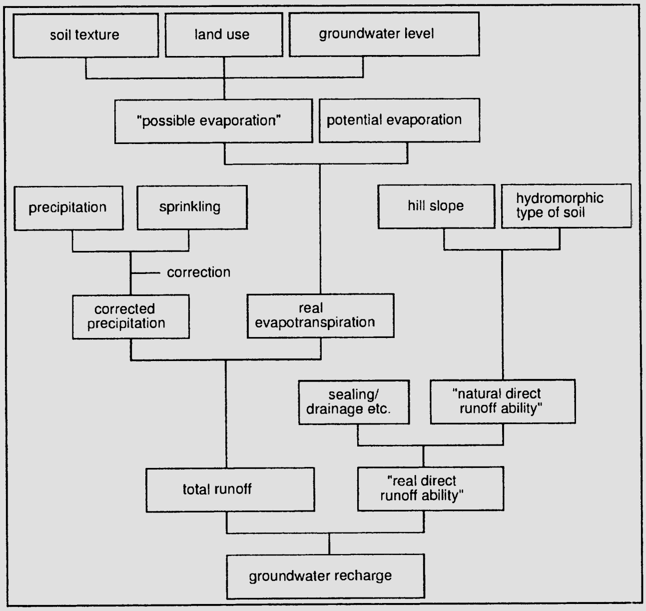


Figure 5.2-4: The assessment of groundwater recharge by combining the methods of Glugla et al. (1976) and Dörhöfer and Josopait (1980)

Groundwater protection against pollution is based on several chemical, physical and biological processes. That is why special investigations for different pollutants are necessary. In Central Europe, several maps exist which visualize the general pollution risk of groundwater in large areas (scales). For a more detailed assessment of groundwater protection the method of Wohlrab and Zepp (in Marks et al. 1992) considers soil texture, soil humidity and groundwater recharge. For specific pollutants special assessment procedures should be used. If the type of contamination is known, much better results are possible in this way (Table 5.2-3). Related methods are published e.g. in Marks et al (1992) and Bastian and Schreiber (1999).

Table 5.2-3: Main parameters for the assessment of groundwater protection from specific pollutants

pollutants	main parameters
nitrate	field capacity, climatic water balance, soil moisture, microbiotic activity
heavy metals	metals and their compounds, pH-value, contents of humus, clay and sesquioxides
organic pollutants	organic compounds, chemical environment, pH-value, content of humus, clay and sesquioxides

Climatic balance characterizes the ability of the landscape to compensate bioclimatic stress in settlements, industrial regions and along traffic routes. Generally climatic balance is based on the production of fresh air in more or less unimpacted areas, the transportation of this fresh air to the polluted regions, and the exchange of the air according to natural peculiarities of the landscape (e.g. relief, roughness of surface). The determination of the climatic balance requires close-meshed measurement networks including the mobile recording of data from both the ground and the air. With the help of this data and detailed models of surface and land use, simulation of fresh-air streams and exchange is possible (e.g. Gerth 1987).

Spatial planning normally cannot carry out such expensive measurements. That is why empirical methods are often preferred, such as the method published by Alexander (in Marks et al. 1992). It is valid only for hilly and mountain regions containing polluted areas in basins or valleys. The point-assessment procedure considers the size of fresh air formation area, land use parameters, inclination, slope length, curvature and surface roughness. Nevertheless, quantitative results are not possible. For that, special detailed climatic investigations are necessary.

The lack of information is a serious constraint in landscape analysis and planning; this is particularly true for biotic landscape elements such as flora, fauna and biotopes, because they change permanently and very quickly. A possible approach to assess the most complex landscape **habitat function** (Figure 5.2-5) involves a network of hierarchical sample areas and methods varying in scale and intensity of examination (Table 5.2-4). Similar or analogous methodological frameworks can be elaborated for the investigation of other natural potentials and landscape functions.

Figure 5.2-5: Functions of undisturbed bogs are e.g. water retention and as a habitat: The Endla bog, Estonia (Photo: O. Bastian 2001)

In essence, the analysis and interpretation of habitat values can be obtained by studies at five (to six) levels of investigation. Levels 1 and 2 do not require fieldwork but are confined to existing data (satellite data and aerial photographs, topographical and thematic maps). For levels 3, 4, and 5, precision and expense increase from land use and biotope-type mapping (level 3), via the mapping of vegetation, flora and fauna (level 4), to the analysis of those organism groups that are rather difficult to record (e.g. soil fauna, arthropods, fungi - level 5).

Table 5.2-4: Scale ranges, test areas and approaches for evaluating landscape habitat value (from Bastian 1992, 1999a)

level of research	test area	scale	approaches
without field-work			
1 a	country	1:200,000	interpretation of geocomponents, environmental media, land use impacts,
1 b	district	1:25,000	analysis of biotope-linking, assessment of floristic and faunistic maps
2	parts of a district, communities	1:10,000	as level 1, but a more detailed registration
with field-work			
3	as in 2	1:10,000 and smaller	biotope mapping (biotope types, landscape elements), land use analysis (detailed)
4	small sample areas	as in 3	analysis of actual vegetation (plant communities, vegetation forms, indicator species), landscape elements/biotopes, habitats)
5	as in 4	as in 3	registration of groups of species difficult to detect (irregularly appearing, mobile, living in concealment) or hard to determine
mainly laborative methods			
6	point-wise sampling	as in 3	morphometrical and biochemical (ecophysiological) investigations (esp. within biomonitoring programs)

Criteria (interpreted indicators, see Chapter 3.3) of landscape habitat value are e.g. (Bastian 1996):

- **Rarity**: Rare/threatened species are, as a rule, dependent on very specific site conditions. They are especially sensitive to human influences. Their occurrence reflects completeness, quality and the protective value of an ecosystem or landscape.
- **Degree of naturalness/hemeroby** reflect the strength of human influence, especially the degree of transformation of natural vegetation cover by man. This is closely related to ecological stability (see Chapter 5.1).

- **Diversity**: The principle of diversity is of fundamental importance in the functioning of landscape balance, not only concerning the maintenance of genetic diversity, but also with regard to the reduction of undesired matter and energy fluxes and the aesthetic value. There are certain, but no absolute connections between diversity and ecological stability, too (see Chapters 5.1 and 7.7.3). According to Haber (1979b) there are three types of diversity: α- or species diversity, β- or structural diversity (within one landscape element, e.g. different vegetation layers) and γ- or spatial diversity of mosaics of very different, but homogeneous spatial units.
- **Age**/length of development: Ecosystems which need a rather short period for their development (if the necessary environmental conditions and genetic resources are available) are less valuable (for nature conservation) than those needing longer periods (Table 5.2-5).
- **Spatial (biogeographical) aspects** (see Chapter 2.8):
  - biotope size: The larger an ecosystem is, the better are the chances for the maintenance of stable populations, both because of population-genetic causes and also with regard to negative influences from the surroundings. Closely connected with that is the
  - degree of isolation of the biotope. The more the character of the surrounding land use differs, the more unfavorable are the circumstances for exchange between populations and consequently for their stability.

Table 5.2-5: Duration of development (age) of several ecosystems (biotope types) (from Bastian 1992a, 1999a)

age class	development (years)	examples
I	< 5	short-living ruderal vegetation, segetal communities, initial stages of rough meadows on sand, vegetation of clear-felled areas
II	5 - 25	meadows poor in species, herbaceous perennial vegetation, ecotone communities, vegetation of eutrophic waters, poor rough meadows on sand, ruderal shrubs and initial woods
III	25 - <50	older (but still little differentiated) hedges and shrubs, oligotrophic silting vegetation, relatively rich reeds, meadows, mesoxerophytic meadows and heaths
IV	50 - <200	relatively rich vegetation of forests, bushes, hedges
V	200 - <1000	fens, transitional bogs, old richly differentiated dry meadows and heaths
VI	1000 - 10,000	peat bogs, old fens, forests with old soil profiles

For biotope assessments it is common to combine these parameters with the help of mathematical formulae (like addition, multiplication of single parameters) or with the help of the benefit-value analysis and so-called ecological combination matrices. **Complex biotope values** are very welcome for planning purposes, because they are better to handle for authorities. But one should not forget the disadvantages of such complex values (see Chapter 5.3.4). The assessment of landscape habitat function should not be restricted to the present state, but it should also point to necessities and goals of landscape development/management (Table 5.2-6).

Table 5.2-6: A possible gradation for the evaluation of biotope types (from Bastian 1999a) 1 - highest to 5 - lowest value

1 - Very endangered and essentially declining biotope types with high sensitivity to human impacts and with long time for regeneration; habitat for many rare and threatened species; mostly a high degree of naturalness and only extensive or no use, hardly or not at all replaceable, absolute priority for protection
2 - Endangered and declining biotope types with a medium sensitivity, with medium to long regenerative times; important as habitat for many, partly threatened species; a high to a medium degree of naturalness, medium or low land use intensity, only partly replaceable; priority for protection or improvement
3 - Common endangered biotope types with low sensitivity, rather quickly regenerable, as habitats at best of medium importance. As a minimum, present state should be maintained but ideally enhancement to more valuable biotopes should be achieved.
4 - Very common, heavily impaired biotope types, as habitat of minimal significance, low degree of naturalness, short regenerative times, transformation to ecosystems being closer to nature is desirable
5 - Very heavily impacted, devastated or sealed areas, an improvement of ecological situation is necessary

5.2.3 The assessment of heterogeneous spatial units

The dimension problem, i.e. the choice of an appropriate scale including corresponding landscape objects (as indicators) and methods, is very important for the assessment of landscape functions and for the elaboration of management goals (see Chapter 7.2). The methodological problems in small scales (i.e. for small areas and in great detail) have been solved to a great extent (e.g. Bastian and Schreiber 1999, Marks et al. 1992). Dealing with large areas (in meso- or macro-scale), however, is difficult due to the shortage of appropriate data and methodologies, but especially because of the heterogeneity of reference areas (e.g. landscape units).

In principle, the following **fundamental ways of solution** are possible (Bastian et al. 1999):

– **holistic approach**: the consideration of heterogeneous spatial units as an entity without disintegrating them into smaller constituents,

- **partly selective approach**: their division into different parts with defined location or the consideration of characteristic basic units as mosaics (patterns), and
- **elementary approach**: their full disintegration into separate parts (landscape components or elements) or the general denial of the existence of complex spatial units.

Table 5.2-7: Degrees (and spans) of the potential erosivity (with reference to slope and soil cover, without regard to land use) according to possible combinations of both factors (from Bastian et al. 1999)

slope classification	>0.5°-3°	>3°-7°	>7°-16°	>16°
pile of rocks, gravels and their mixtures with sand	1	1	2	2 - 3 (2)
sands, mixtures of loam and loamy sands with coarse erosion material	1	1 - 2 (2)	1 - 4 (2) *1 - 3 (2)*	2 - 5 (4) *2 - 5 (3)*
loamy sands	1-2(1) *1*	2 - 3 (2)	3 - 5 (4)	4 - 6 (5) *4 - 6 (4)*
sandy silts	1 - 2 (2) *1 - 2 (1)*	2 - 3 (2)	2 - 6 (4) *2 - 5 (4)*	4 - 6 (6) *4 - 6 (5)*
silts	1 - 2 (2)	2 - 3 (2)	4 - 6 (5)	6 *5 - 6 (6)*
loams, silty loams	1 - 2 (2)			

explanation: erosion danger: minima - maxima (average), bold: r-factor ≈ 60, italics: r-factor ≈ 50, normal: both r-factors

The assessment of landscape functions for heterogeneous reference units at a medium scale was devised by Bastian et al. (1999) as follows:

- **biotic yield potential**: Assessment of the soils predominating in the reference unit,
- **resistance to soil erosion**: Simulation and assessment of all possible combinations of the parameters soil texture, slope, land use with the help of a matrix, and considering all possible spans of values (Table 5.2-7). This matrix is a system of rules. In boxes (of the matrix) several degrees of value (heterogeneity!) can be derived; fuzzy decision systems should be applied.
- **runoff regulation**: Calculation of a medium runoff-quotient for every unit with the help of slope and soil parameters; evaluation of average numerical values of the main land use types; subsequent division of the land use by the runoff-quotient,
- **groundwater recharge** (see Figure 5.2-6): Aggregation of results which were obtained for the smaller homogenous units,
- **groundwater protection**: Application of results from an existing meso-scale map regarding the predominating values in every unit,

- **habitat function**: Calculation of aggregated values through an ecological combination matrix from the following indicators: degree of naturalness of vegetation (dominance and combination types/mosaics according to Schlüter 1992, 1995), share of valuable biotopes in the reference unit including size and isolation/connectedness of these biotopes,
- **potential for recreation**: Assessment of the landscape scenery (which is caused by natural factors and land use) by structural landscape parameters.

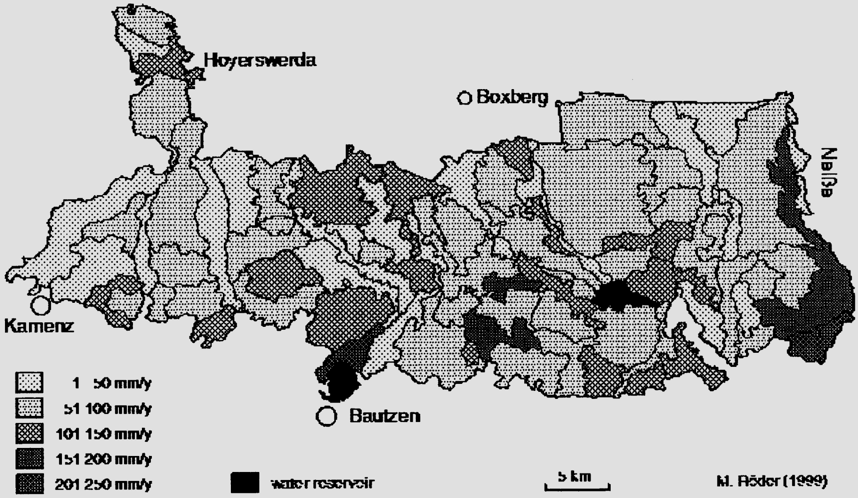


Figure 5.2-6: Landscape functions (example: annual average groundwater recharge) in heterogeneous reference units (microgeochores) in the Upper Lusatian Heath and Pond Landscape (Saxony, Germany)

5.2.4 Changes in landscape functions

The assessment of landscape functions/natural potentials is not only important for the status quo, but also for former (and future) situations. Usually, in landscape change studies, only symptoms are described, such as land use and land cover changes, loss of landscape elements, biotopes, biocoenoses, and decrease in biodiversity. Thus, it is hardly possible to grasp the character of landscape changes, especially with regard to functional aspects and relations. With the help of landscape functions, however, it is much more possible to focus on functional aspects and to interpret ecological functioning and usability of landscape at different times (Figure 5.2-7). Thus, a more dynamic view and methodology in landscape ecology and planning is promoted here.

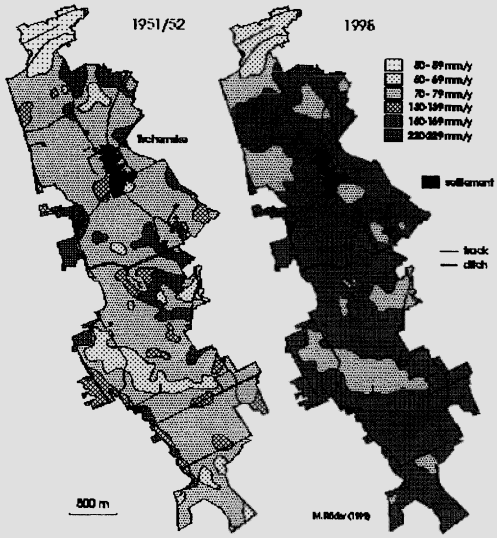


Figure 5.2-7: Change in the medium yearly total runoff in a test area in the Upper Lusatian Heath and Pond Landscape biosphere reserve (Saxony, Germany) between 1952 and 1998 (from Röder et al. 1999)

5.3 Landscape evaluation

5.3.1 The essence of evaluations

An **evaluation** is the crucial step in processing analytical data for decision-making and action, i.e. to convert scientific parameters into socio-political categories. This was defined by Neef (1969) as the "transformation problem". Generally, an evaluation is a relationship between an evaluating subject and an object under evaluation (Bechmann 1989); the assessment of the degree of achievement of an objective compared with the original objective.

A **landscape ecological evaluation** is related to the capacity of the landscape to perform its essential functions ("natural balance"). Thus, we depart from purely recording objectively the state of the landscape and its changes, and create the suppositions for directed interventions through landscape management. Ecological facts, effects, and contexts are translated into parameters which are relevant to human society in order to draft goals and political decisions. At best counting, measuring, classifying and similar procedures can be regarded as preliminary stages but not as complete evaluations; they are not sufficient for immediate application to practical purposes (e.g. landscape planning). This concerns the determination of numbers, rarity, diversity of species, age and naturalness of ecosystems, too. At first, these parameters represent "only" ecological facts without any indications for actions.

Figure 5.3-1 may be regarded as a model for **evaluation** procedures **on different levels**: The analysis is followed by data processing (e.g. classification, comparison, combination). Only the second level of evaluation proves to be an evaluation in the strict sense (comparison of the present situation with the goals), a real transformation (of scientific data into social parameters) takes place. First, it is a matter of (a) specialist evaluation(s) within the competence of nature conservation and landscape management. The transition from a monosectoral view (e.g. the ornithological value of a woodlot) to a multisectoral view (the significance for the protection of species and biotopes to achieve the natural balance in the broadest sense) represents a growing complexity. On the third level of evaluation, a reconciliation (political weighing of interests) with other policies, land users (outside of nature conservation) and stakeholders is realized (Figure 5.3-2).

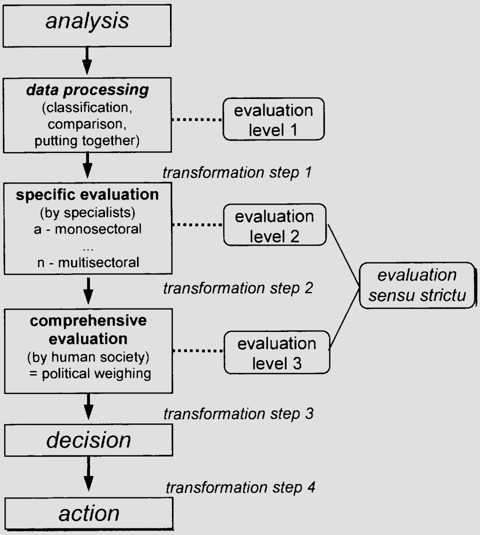


Figure 5.3-1: Model of an ecological evaluation with different levels (transformation steps, from Bastian 2000b)

This is the basis of decision-making and, finally, of concrete actions (implementation of results). Essential suppositions for the landscape evaluation and for the planning and projection of measures are scientifically based goals which are created by human society and which are formulated as laws, standards, limits, and concepts (see Chapter 7.2). Evaluation and **environmental goals** (visions) are interrelated. A concrete evaluation result essentially depends on subjective and inter-subjective value systems. Conversely, results of evaluation can influence goals: e.g. the statement of unfavorable environmental conditions can trigger actions to find a remedy.

An **evaluation sensu strictu** indicates the extent and the manner of necessary measures. It provides the norms and orientations for the concrete action which is always a decision between several options. For evaluation demanding general validity, a consensus of the human society is necessary; it is the matter of conventions, and thus depends on the situation and time. Therefore, evaluation can never be objective. The skill of evaluation is the combining of facts and standards of value to achieve a sensible judgement. Evaluations always depend on the competence of the evaluating subject. On no account should subjectivity mean arbitrariness or irrationality, since an evaluation is or should be comprehended also by other subjects (intersubjectivity). Necessary preconditions for this are: facts and standards of value are disclosed and they are combined in a systematical manner, i.e. using well-defined assessment procedures (Bechmann 1995). The **aim of formalized evaluation algorithms** is to rationalize the (landscape) planning process and to increase the acceptance of the results by human society.

Figure 5.3-2: The results of landscape evaluation also depend on each social group involved. Rich flowering but less productive meadows are appreciated by nature conservationists and tourists, but not so by farmers: Colorful mountain meadow near Zazrivá (Kysucké low mountains, Slovak Republic) (Photo: O. Bastian 1985)

5.3.2 Assessment methods

There is an immense number of different assessment methods. A systematization is necessary. We can distinguish, for example, numerical-additive and -multiplicative combinations (point systems, ranking), logical combinations (matrices, decision trees, dendrograms, AND/OR-combinations) and mathematical-statistical combinations (cost-benefit analyses, benefit analyses of the 1st and 2nd generation).

Among mathematical methods **point systems** which aggregate several criteria by summarization or multiplication are especially important, as are index approaches which process the criteria with more or less complicated arithmetical operations in order to achieve a single unified number (an index). Such arithmetical operations, however, are more and more criticized and should be avoided in many cases, because of (Nipkow 1997):

- the danger of subjective parameter weighting,
- ecosystem characteristics are seldom independent of one another, and there are correlations leading to interferences, redundancies and cumulations, and
- the inflexible algorithms of mathematical methods, especially with regard to region-specific conditions (e.g. data availability).

Marks et al. (1992) reduce all ecological evaluation methods to four main groups: assessment of ecological:

- **suitability** of ecosystems and landscapes for certain demands of human society (e.g. soil productivity),
- **loads/impacts**: impacts to/damages of ecosystems by human influences (e.g. soil compaction, industrial emissions),
- **value**: diversity, naturalness, perfection, healthy, functionality of ecosystems and landscapes (e.g. the "value" of a landscape structural element for a microclimatic amelioration or for an animal population),
- **risks** or effects: risks of environmental impacts to nature and landscape which can cause harm to the ecosystem balance (e.g. the risk of road construction).

Further aspects of classification of assessment methods are, for example, the related branch of land use, the data basis involved (number and kind of criteria or indicators), the complexity and complicated nature of the approach, the method of data processing and the form of representation of results.

In the case of **economic evaluations**, the price (expense, costs) is the common comparable reference unit. For many ecological, ethical and aesthetical evaluation problems, however, it is very difficult or even impossible to calculate monetary values. Non-economic evaluation approaches often are a more sensible alternative, because essential natural values cannot be encompassed by a utilitarian, quantifying value system.

5.3.3 Scaling

Scaling in assessment procedures can be realized in a cardinal manner (true measurements, ranking with defined distances) and/or in an ordinal way (determination of ranks and nominally i.e. presence/absence of an object or parameter). The choice of a **suitable type of scaling** depends on the available data and the particular purpose. For many areas and facts in nature conservation and landscape planning an ordinal scaling is sufficient, whereas, for example, for the compensation of environmental impacts quantitative comparison is needed. The disadvantage of nominal forms (+/-) is the missing scope for weighing two things against each other. In comparison to formalized (quantitative) methods, **verbal-argumentative (qualitative) evaluations** can be advantageous, especially in order to (Hübler 1989):

- include facts which cannot be quantified at all (e.g. the "value" of a bird, the beauty of a flowering meadow),
- mediate the results to laymen,
- consider special conditions much better,
- bridge the lack of concrete goals for environmental quality,
- get by on low cost and time expenses, and to
- avoid a subjective weighting of criteria.

Risks/disadvantages of such qualitative evaluations are the

- insufficient clarity (comparability),
- more difficult to justify (comprehensibility), and
- difficult processing by computers.

Both qualitative and quantitative approaches can be combined, for example, in environmental impact assessments (see Chapter 7.4). At first, using a computer-supported quantifying method, a preliminary evaluation and a reduction in the number of variables is carried out, and then, the remaining variables are evaluated qualitatively, i.e. with verbal arguments.

Today, linear allocations and combinations of values are most usual. Admittedly they are easy to handle, but in many cases they are not adequate for complex natural systems. Non-linearity is very much a characteristic of natural systems. That is why, logarithmic or exponential allocations of values are also appropriate. The transformation of observations and measurements into values (according to an appropriate ordinal scaling) can be realized by so-called "condition-value-relations" (Plachter 1992).

The **optimal number of ranks** also depends on the actual task. Evaluation methods should lead to three or five, at maximum, seven degrees. As a rule, more degrees are not appropriate or justifiable. They will not contribute to better decision-making, but confuse rather than clarify the specialist's position. In any case, the number of degrees should be odd to avoid a mean value (Auhagen 1997). If the differentiation is too detailed (too many degrees) the cases with no clear-cut borderlines will greatly increase. It is very important, that (Reck 1996):

- the differentiations are relevant for (practical) purposes, e.g. planning,
- well-defined rules for allocation exist,
- a reliable comparability of weighing up in different planning procedures is achieved, and
- the degrees of value can be understood logically.

5.3.4 Demands on evaluation methods

Because of the existence of very different standards of value, comparing results of evaluations is often difficult.

An **universal algorithm** for landscape ecological evaluations includes the following steps:

- definition of the aim of evaluation,
- choice of suitable methods,
- definition of criteria, graduations of scales, and restrictions,
- analysis of necessary ecological data,
- weighting and combination of the data analyzed, and
- interpretation of the results.

Ecological evaluations should meet the following **minimum demands**:

- logical structure of the method as the basic precondition,
- clear distinction between the steps "analysis of data" and "evaluation",
- no use of the term "evaluation" without any relation to value judgements,
- consideration of present knowledge and evaluation criteria,
- validity, plainness and flexibility of approach,
- appropriateness of the chosen methods for the analyzed landscape area and the necessary precision/scale,
- relevance of the evaluation methods and criteria applied, as well as the necessity and aims of each evaluation step,
- taking all essential factors and conditions into account,
- reliability of analytical data and ecological contexts,
- documentation of the type of data applied, description of its quality and completeness,
- appropriate scaling of all parameters,
- accessibility to necessary analytical data in a justifiable time,
- transparency of data analysis and processing,
- scientifically sound, logical derivation of all aggregation steps and their comprehensible presentation; documentation of essential interim results,
- explanation of the relations between single criteria,
- sufficient differentiation within the evaluation steps,
- plausibility of rules for allocation of values to analytical data,

- formalized methods must not demand too much quantification from the basic data, and
- unambiguous, exact and significant data as results which should be suitable for the presentation in maps.

Obviously, all evaluation methods satisfy, at best, some of these demands. There is no ideal procedure. All have specific advantages and disadvantages, which favor them for different tasks. Sometimes, it is better to use several approaches simultaneously. The peculiarities of the actual case should always be considered. A critical view, sometimes also a modification of the chosen approach, is necessary in order to achieve suitable results. According to Leser (1983) and Hase (1992), the **main failings of existing evaluation procedures** are: the poor consideration of ecological contexts, the feigning of objectivity by a seeming quantification of (qualitative and semi-quantitative) facts, difficulty and poor intelligibility. There is often no separation between analytical and normative levels i.e. the fundamental differences between the ecological research and evaluation are not considered sufficiently. The natural processes are mostly too complicated for our imagination, and certainly for formalized evaluation schemes. Knowledge and data basis are too poor, but landscape planners and ecological experts usually cannot wait till the completion of basic research (which will never be achieved), since propositions for decision-making are expected immediately. Thus, for the time being we must be content with the available knowledge, even at the risk of fallacies.

In conclusion it should be mentioned that an aggregation of several ecological parameters always contains uncertainties (Marks et al. 1992). The combination/summarizing of entirely different facts respecting ecological characteristics as complex statements of so-called **overall-ecological value** is not meaningful at all. From the final result it is not even possible to conclude approximately the parts of the evaluation. If an evaluation approach attempts to solve too many special tasks, or if within one step of the procedure too many partial goals are integrated, the applicability is lost or becomes too complex to be comprehensible.

There are several problems resulting mainly from the **heterogeneity of the landscape**:

- uncertainty in the classification of the input data,
- data gaps and inaccuracy in the data,
- variability in time and spatial heterogeneity, and
- reduced availability of representative indicators.

Therefore, traditional assessment methods have to be replaced by a data model that takes the degree of variation into account, and that also allows statements on an uncertain and incomplete database. The **fuzzy set** theory provides methods for allotting objects into categories in which the transition from membership to non-membership is gradual rather than abrupt. As a result of the model's application one gets all the probability values. These values describe the degree to which an element belongs to the observed set (Steinhardt 1998, Syrbe 1996).

5.4 Landscape assessment and multicriteria optimization[2]

5.4.1 Initial questions and functional assessment

As we know, landscape has to fulfil various functions simultaneously on the same area. This inevitably leads to land use conflicts. How should this situation of conflicting aims concerning future landscape development be dealt with? Traditional assessment methods have to be upgraded for a methodological framework to mediate between the different goals and to provide a compromise solution. Special attention needs to be paid to maintaining and restoring regulation functions. Nevertheless, other functions must not be neglected. Therefore, interest is primarily directly towards methods which consider a number of different functions simultaneously in integrated model systems.

Landscape ecological assessment begins by seeking **guidance criteria** oriented towards regulatory and other functions. As is standard practice in landscape planning (see Chapter 7.3), the survey region first has to be demarcated and basic data have to be compiled. The models, goals and a selection of the landscape functions taken into account should be discussed in internal expert discussions. The **selection of landscape functions** depends on the model chosen for the study area and the relevant issues, and takes place after an initial landscape analysis. Although the integration of as many functional levels of consideration as possible theoretically best reflects the **multi-functionality** of the landscape, for practical reasons this approach should be avoided. It should be borne in mind that an excessively large number of functions will reduce the clarity and comprehensibility of the findings (due to overlapping by functions with a similar effect). The selection of ecological or other functions (optimization goals) should therefore focus on the main ones.

The assessment applied is mainly based on methods described in Marks et al. (1992) and other validated methods in the literature. All these methods

[2] With the assistance of R. Grabaum and H. Mühle; the article was published in a former version in Krönert et al. (2001)

are restricted to an **application on the topological level** (see Chapters 2.1 and 2.2). A selection of assessment methods is listed below:

- soil erosion by water (Schwertmann et al. 1987),
- soil erosion by wind (Smith et al. 1992),
- runoff regulation (Marks et al. 1992), and
- production function (soil indices) in Scheffer and Schachtschabel (1984).

Landscape ecological assessments are carried out in the **GIS** by linking up the corresponding data levels with comprehensible rules. GIS is also used for data acquisition, the further processing of data, presenting scenarios and showing the findings of optimization (see Chapter 6.2). The findings of the assessments are shown in ordinal classes (frequently with 3 or 5 levels). This classification into classes is essential for the further use of the results in the optimization. The main basis for such techniques is a **landscape analysis** (see Chapter 3.2). This entails using the generation of data in the Geoecological Mapping Instructions (Leser and Klink 1988). In the method presented, the possibility of the direct further-processing of data using the GIS (e.g. as a guide for optimization) is of key importance.

5.4.2 Scenarios for land use options

In order to describe future land use, as well as to present the land use changes and their effects on the (landscape ecological) functions, various **scenarios** (see Chapter 4.3) are defined and evaluated with respect to the objectives. Each of these scenarios contains a different scope of land use changes. When defining the objectives and during problem analysis, it is initially determined whether optimization takes place or whether the change in land use can be described with other methods. As far as optimization is concerned, this means that for each function which can be described in an areal manner, an objective is defined based on the evaluating analysis which is to be achieved with a change in land use (for example, the reduction in erosion by at least 30%).

If optimization is used to ascertain land use options, function-related goals need to be formulated. Achieving these aims entails defining restrictions. These include, in particular future, areal percentages of the land use elements under consideration. These areal percentages will not be exact, but will instead be defined within certain limits (for instance the growth of forestland may account for between 6% and 8% of the area to be optimized). The extent to which the goals are achieved can be reviewed after each optimization run. Should it not be sufficient, a new optimization run with different areal percentages can be started at any time. However, it should be noted that as soon as the aim is defined a certain areal percentage corresponding to the original model must be assumed (for example, a very high proportion of forest does not correspond to the model of an open agricultural landscape). Thus compromises are to be sought if the aims are to be achieved.

In addition, decisions will have to be made concerning the exclusion of areas or the exclusion of uses for certain areas. The scenario thus developed containing indications of the goals of future land use changes provides the framework for landscape optimization. The scenario hence corresponds to an initial, more precise specification of the model.

5.4.3 Multicriteria optimization

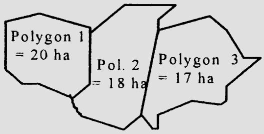
The common approach of superimposing different assessment maps to generate "conflict maps" does not fully meet the requirements of an accurate planning tool. As it only highlights the incompatibility of different land use options when the conflict zones are obvious, it cannot produce the integrated view needed for a planning region.

Grabaum (1996) developed a computer-based method combining landscape ecological assessment with optimization. This formed the basis of the **Method of Multicriteria Assessment and Optimization**, designed for the low structured agrarian landscape near Querfurt (Saxony-Anhalt, Germany) and other sample sites (Grabaum and Meyer 1998). The possibility of linking up assessments based on landscape elements with the method of multicriteria optimization was described by Koch et al. (1989), and then put forward by Grabaum (1996) as a computer-based integrated method.

The **mathematical method** of multicriteria optimization achieves results which can be considered as optimal compromises between different goal functions. These functions may often be mutually conflicting. The assessment results (i.e. the results of each goal divided into classes) are used as coefficients for these functions. Hence, assessments have to be carried out for the entire set of variables. The number of variables is equal to the number of evaluated landscape elements multiplied by the number of polygons. Thus, each landscape element has to be considered on the level of each polygon. A landscape element may completely cover a polygon or share it with other elements (Figure 5.4-1).

Equality **restrictions** (area of polygons) or inequality restrictions (the whole size of the landscape elements) define the boundaries of optimization. Optimization is part of "linear programming" (e.g. Werner 1993). The optimal in this case is defined as follows: A solution (variable assignment) is optimal if a higher value cannot be achieved for one goal without decreasing the goal function value of at least one other goal. This case of optimality is denoted as **PARETO optimality** (Dewess 1985, Wierzbicki 1979). The values of goal functions are in turn used as a criterion to measure the optimal.

These values can be calculated by adding the products of areas obtained as solutions (see areas with values greater than 0 in Figure 5.4-1) and their corresponding goal function coefficients.



Landscape elements: A, B, C

Set of variables:
$x_{1A}, x_{1B}, x_{1C}, x_{2A}, x_{2B}, x_{2C}, x_{3A}, x_{3B}, x_{3C}$

Possible occupation by variables:	x_{1A}	x_{1B}	x_{1C}	x_{2A}	x_{2B}	x_{2C}	x_{3A}	x_{3B}	x_{3C}
	0	20	0	8	10	0	0	0	17

Figure 5.4-1: Set of variables and a fictitious solution (assignment of variables) (Grabaum and Meyer 1998, modified)

The method used here is based on game theory and was elaborated by Dewess (1985). The optimal is calculated by minimizing the maximum difference of each goal value from its optimal value. This method involves calculating optimal values for each goal (without considering the other goal functions). This enables the risks of a monofunctional landscape to be identified. One peculiarity of this method is that the user can interactively calculate an arbitrary series of solutions by weighting each of the goal functions subjectively. The set of solutions is therefore infinite. Optimization is carried out using the software LNOPT (Grabaum 1996). The software has to be adapted to the problem at hand by defining different values. For more information about optimization methods see Grabaum and Meyer (1998).

5.4.4 Optimization aims for conservation goals

After extensive assessments of ecological functions had been carried out in a specific study area, hence enabling the degree of fulfilment of the provisional model to be estimated, **multicriteria optimization** is required in order to ascertain land use options for the nature conservation scenario. This model exemplar could be defined as follows: The study area should preserve the character of an open agricultural landscape with extensive soil protection, an increase in the soil's retention capacity, and the maintenance of high productivity. Economic and social conditions are to be organized such that they are in tune with the preservation or improvement in biotic (biological diversity) and abiotic resources, and that the population can be ensured a sufficient income with high social acceptance of their work. The proportion of biotope structures for nature conservation is to be increased.

Starting from the current state, the ecologically substantiated main aims listed below for the implementation of this model can be formulated for the **nature conservation scenario** following Mühle (1998):

- reduction in soil erosion by water as a contribution to soil protection (function 1),
- improvement in the retention capacity (function 2),
- continuation of production on soils with the highest soil indexes (function 3),
- reduction in soil erosion caused by wind as a contribution to soil protection (function 4),
- increasing landscape and species diversity, and
- creation of biotopes.

The aims of increasing landscape and species diversity and the creation of biotopes can be achieved if single functions/aims are met by changing land use. First of all, the optimization area within the study area must be defined. Although basically all the land evaluated can be covered by optimization, it makes little sense to include built-up areas, infrastructure, surface water, bushes or existing grassland, as their current uses are to be preserved. Hence only cultivated areas should be included. As only the arable land is regarded as the optimization area, the percentage of land relevant for conservation purposes compared to the entire area is somewhat lower.

In order to obtain the smallest common geometry in the GIS for the optimization area, the assessment results of the target functions are divided into separate areas. The restrictions of element size have to be fixed before optimization. This can be done by setting the upper and lower boundaries. Alternatively, the optimization problem can be solved without defining an element size. Other restrictions can be integrated (for example specifying definite landscape elements on a restricted number of polygons).

5.4.5 Maximization and compromises

During optimization, first of all the maximum values of the exemplar functions "reduction of water erosion", "improvement in the retention capacity" and "improvement in the production function" are calculated. The function "reduction of the soil erosion due to water" is a **minimization function** (minimizing potential erosion by the suitable choice of erosion-inhibiting landscape elements); the other two functions are **maximization functions**. As all the aims are maximized by the LNOPT program, the minimization function "soil erosion due to water" is converted into a maximization task by multiplying it by –1 ("maximization of the resistance to soil erosion due to water").

The maximum values can be used to identify the problem areas for the individual ecological functions and to improve them by means of land use changes. The other functions are not considered. Therefore the realization of the results from the maximization of one single function is not recommended.

Consequently, a **compromise** has to be found. For this purpose, the individual functions can be weighted so that in each case a different 'optimal' compromise can be determined. For the optimization area, three compromises were calculated for each scenario. They differ in terms of the weighting of the individual goals (Table 5.4-1). First of all, all the objectives are weighted equally (1:1:1). Other possibilities include favoring two functions over the third function (101:101:100 in compromise 2) and the gradual preference of each function (75:74:73 in compromise 3). Weightings describe the preference structure for the goals in a model system. The weightings are multiplication factors to calculate the variation of equal weighting. If the differences of weightings are too stark the results incline to the maximization of one goal (fictive compromise weighting: 3:1:1).

Table 5.4-1: Weighting of the functions in compromise optimization

function	compromise 1	compromise 2	compromise 3
water erosion	1	101	75
retention capacity	1	101	74
production function	1	100	73

The improvement in the individual functions can be gauged from the functional value. The functional value is the sum of the products of area size, containing element x, and its assessment.

In each case, the maximum values and the compromises shown in Figure 5.4-2 are highlighted in bold type. It can be seen that in the scenario "7.5% conservation area", the current functional values are significantly less than the functional values of optimization (compromise 1) for the two regulatory functions "erosion protection" and "retention". By contrast, the current functional value for the production function is higher than the optimal values – for during reorganization, farming is ceased on some areas. The difference depends on the area envisaged for the new biotope structures.

In Figure 5.4-2 it is apparent that the functional values for current use (solid line) are partly far below the optimal values of the compromise solutions (with the exception of the production function). Optimization thus brings about an improvement in the regulation functions (line for compromise 1). It should be noted that the three axes in Figure 5.4-2 are completely independent of each other and for graphic reasons their origin cannot be shown. The **Utopia Point** consists of the maximum values of the individual functions. It is actually a theoretical value, because the maximum values of all the functions included in the method never can be reached simultaneously owing to their opposing aims.

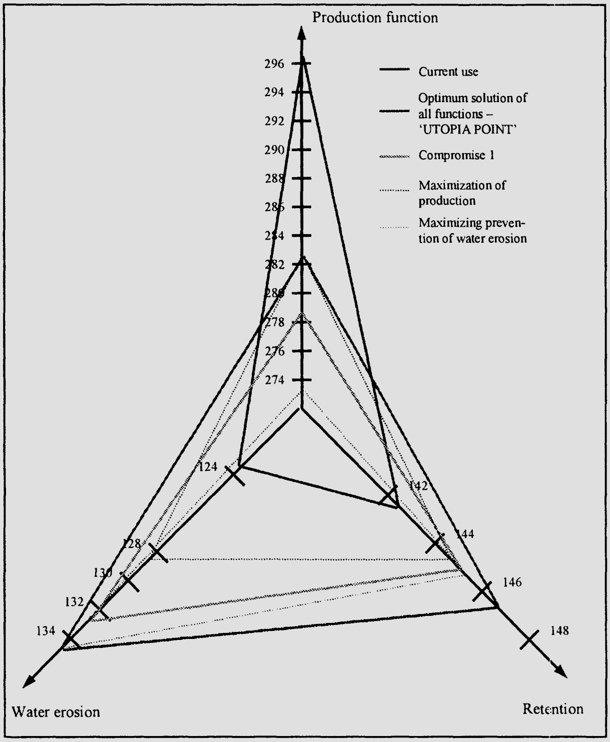


Figure 5.4-2: Comparison of (target) function values (× 106) of various optimal solutions with the current use for scenario 7.5% conservation area (Grabaum and Meyer 1998)

5.4.6 Summary and conclusions

All in all, there are many ways to improve the presented method and make it a powerful instrument for planners that can help tackle diverse requirements in a planning region. Functional assessments and optimization used in turn are a powerful instrument in the preparation of political decisions.

One particular strength of the method is its constant processing in a GIS up to the preparation of a draft landscape plan (see Chapter 7.3), which is produced in an area-specific manner, and every step of which is comprehensibly drawn up on the basis of vector information. This means that goals (e.g. from the conclusion of the model) can be expressed more precisely for a specific location while simultaneously taking the whole study area into account. Another major advantage is that an infinite number of scenarios can be produced by changing the weighting. Therefore, the further development of the method must focus on the problematic, normative selection of the scenarios to be calculated and the weightings to be used. In future it will be possible to use decision-support methods for the selection of functions.

5.5 Landscape perception and aesthetics

5.5.1 Aesthetics and the perception of beauty

People's perception of the landscape through the senses results not in an objective picture, but rather a subjective overall impression (Figure 5.5-1). **Aesthetics** is the **study of beauty and its perception**. It can be expressed in a simplified manner as an object–subject model. If we consider the aesthetic relationship between a human and the landscape, the landscape is the aesthetic object, while the person perceiving it is the aesthetic subject. The aesthetic object triggers a sense of aesthetic perception; a process of aesthetic perception takes place in the **aesthetic subject** (Nohl 1980, Wöbse 1981). Using this model, landscape aesthetics can be defined as a branch of aesthetics dealing with the interrelations between the landscape and human perception. The main factor concerned is the beauty of the landscape.

Figure 5.5-1: While perceiving landscape, not only an image but a view, an opinion and an overall impression are emerging: Scenery in the Allgäu Alps (Bavaria, Germany) (Photo: O. Bastian 1996)

A person's aesthetic appraisal of objects such as the landscape and sections thereof results from the **interplay of facts and values** concerning the object which are consciously or unconsciously associated with it by the person. Accordingly, beauty is not an intrinsic characteristic of something, but instead a value attributed to it by humans (Wöbse 1993). Beauty is felt emotionally; aesthetics is a rational appraisal.

The duality of perceptible form and mental image also moulds the concept of the appearance of a landscape. The appearance of a landscape means more than the objective landscape; the term also expresses that the landscape is subjected to an (aesthetic) appraisal (Boulding 1956, Lynch 1960). Both terms – **landscape aesthetics** and **landscape appearance** – hence mean the same thing. The difference is that "landscape aesthetics" stresses the process of appraisal, while "landscape appearance" expresses the result of aesthetic appraisal (Wöbse 1993).

5.5.2 Perception of landscapes

Perception refers to the process of receiving and processing environmental information. Since this process always takes place when carrying out some sort of activity, it has a functional nature (Becker and Keim 1972). The part of perception which involves processing environmental information is known as **experience**.

A landscape is always assessed depending on how it is experienced by an individual in this landscape, and is therefore dependent on location. The location itself determines the viewpoint of the landscape perceived (angle of vision, direction of vision, distance). Consequently, rather than having one single appearance, a landscape actually consists of very different landscape appearances (Hübler 1991).

The subjective process of experience must be regarded as being as equally realistic as any other scientific findings (von Weizäcker 1992). Every single person perceives his or her surroundings via their sensory organs. Consequently**, appraisal and perception are subjective**. The process of perception is a very complex, holistic process. It can be described via process levels of perception (Figure 5.5-2).

This **process of perception** can be divided into the following four levels (Capra 1991, Trieb 1977):

- **spiritual world**: the environment and "the great whole" as determined by God and/or nature,
- **existing world**: the objective temporally defined world independent of the perceiver; it is also quantifiable reality,
- **effective world**: the environment as perceived through the senses (sight, hearing, smell and feelings as a whole), and

– **experienced world** (subject level): subtle picture of the effective world on the basis of specific personality traits.

The object of spatial planning is mainly the experienced and the effective environment.

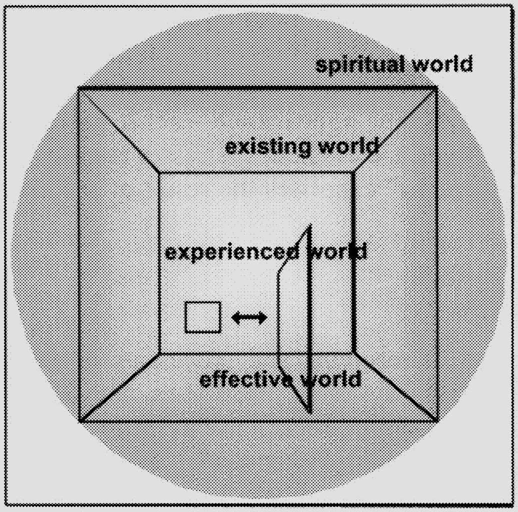


Figure 5.5.-2: Levels of perception (draft: Panse 2001, unpublished)

The fact that the landscape cannot be perceived **and experienced as a whole is partly due to the physical** conditions of the environment, as well as the **subject's limited perception capacity** (Schafranski 1996). Perception is always synaesthetic. **Memory** plays an important role; if it were not for memory, perception would be impossible. The formation of the subject's personality depends on memory. Accordingly, the appearance of a landscape is a combination of perceived, remembered and expected elements (Borgeest 1977). Nohl (1990) summed this up as follows: "Whether we regard a landscape as beautiful is by no means merely determined solely by what we see or what we find out through our senses. One decisive factor is also what we know (or think we know) about the landscape." Similar findings were produced in an American study, in which orange-colored pine stands on photographs tended to be regarded more positively the larger the visible amount of discoloration. A control group which had previously been informed that the discoloration indicated pine disease was of the opposite opinion (Buhyoff et al. 1979).

The aesthetic appraisal of the landscape depends on mood, expectation, motivation, attitude, values, professional activity, experience, knowledge, world-view, needs, etc. Therefore perception is also affected by **social factors**, and is open to **manipulation** and **motivation**. Every era of cultural history has its own aesthetic ideas and values upon which the styles of landscape architecture are based.

5.5.3 Aesthetics in the planning process

If landscape aesthetics is to be included in **spatial planning**, a close association is needed between scientific scales and human subjectivity.

The need to arrange the effective environment in aesthetic terms is considerable. After all, the traditional cultural landscape which has evolved over history is being increasingly changed (see Chapter 4.1). The landscape is becoming increasingly mechanized owing to facilities such as wind turbines and transmitter masts; moreover, objects of high historical and cultural value such as castles, country estates and parks, old cemeteries and windmills are often neglected. This has a negative impact on how the landscape is experienced (since the perceiver feels less at home there, receives less inspiration from the landscape than before, etc.).

Consequently, there is a considerable need for planning activities. The beautiful landscape together with the countryside are incorporated as a model into **four-dimensional planning** (i.e. the planning of space and time) within the planning process for urban development and landscape architecture. The ever-growing importance of artistic creativity and emotionality as well as the need to reverse the declining sensory component in the relationship between mankind and nature result in beauty being regarded as an independent value.

Aesthetic appraisals of the landscape are carried out at all planning levels. They mainly result in proposals to maintain and improve landscape beauty. Concepts of landscape aesthetics are supposed to prepare aims and schemes, and to highlight ways and visions for their translation into practice. Since a very large number of **appraisal methods** exists, only a representative few can be mentioned here.

Simple appraisals of landscape aesthetics are, for instance, possible in the method developed by Kiemstedt (1967) to determine "a diversity value". The diversity value is based upon the premise that the value of a landscape increases with its diversity in land use and landscape elements.

A procedure elaborated by Syrbe (in Bastian et al. 1999) uses the following three criteria: the nature of the landscape (its pecularity), its diversity and degree of naturalness. It takes as reference units microgeochores (see Chapters 2.2 and 6.1). Appraisal takes place on the basis of the three equally weighted criteria. These in turn comprise individual indicators which are regarded as either positive (enhancing the landscape's appearance) or negative (impairing it). Indicators of the nature of a landscape include the proportion of valuable biotopes, since such areas are characterized by rarity, are very sensitive, have prestigious value, and are significant for cultural history. Consequently, their disappearance over a large area would represent a great loss to the nature of a landscape. Negative indicators apply to a range of phenomena such as industrial plants and roads etc. which are eyesores, loud or emit odours. Indicators of landscape diversity include the number of different land use types, the amount of cleared farming land (negative), and the number of different slopes (positive). Nearness to nature corresponds to the vegetation's degree of naturalness.

In addition, many other methods have been developed which can be variously classified, e.g.:

- Wöbse (1984): user-independent and user-dependent methods,
- Hoisl et al. (1985): spatial-normative and psychological-empirical procedures,
- Nohl (1991): geographical, physiognomical and psychological-phenomenological approaches, and
- Krause (1974): observational researching and experimental methods.

The main aspects of a **district's landscape appearance** can be illustrated more clearly by generating a synthetic complex landscape appearance (Böhnert et al. 1996) using the **example of the biosphere reserve "Upper Lusatian Heath and Pond Landscape"** (see Figure 4.2-1).

This synthetic landscape appearance is made up of characteristic elements of the actual landscape appearance of the respective landscape unit (microgeochores, see Figure 6.1-6). It combines horizons and backgrounds with pictures and the foreground, encompasses whole areas and fills them with detail. Since analyzing the synthetic landscape appearance is designed to identify the characteristics of the landscape, it also performs the function of a model (see Chapter 7.2).

Based on these investigations, the author compiled a **rambler's map** of the biosphere reserve showing (as pictograms) the following sights perceived as aesthetic features: vantage point, important sight relations, observation point, castle/palace/manor, park, church/chapel, historical cemetery, museum, other monument, historical center, notable building, notable mill, avenue, and individual tree of note.

One reason why aesthetic appraisal has become so important is the boom in **wind parks** in Germany. Every observer's subjective attitude to wind parks varies depending upon what they know and their opinion of wind power. Apart from any economic doubts concerning the feasibility of wind power (assuming any still exist) and its actual or alleged ecological advantages (such as conserving fossil fuels), wind turbines take some getting used to, since they are a bit of an eyesore and also rather loud. Moreover, their impact on the micro-climate and birds' migration routes has not yet been conclusively explored.

In the planning example (part of Sohland a.R. in eastern Saxony, Germany), six wind turbines (WT) are to be built. Sohland a.R. is a linear village 6 km long in which the individual houses each have their own fields at the rear, and is adjacent to a number of high voltage power lines. As a result, the landscape appearance to both the west and the north has been visually impaired for decades.

To ensure the spatial concentration of the wind park, the individual turbines are to be built near the overhead power lines and spaced as close together as possible. Since the turbine masts must not be allowed to dominate the landscape, they are to be as slim as possible and taper upwards. They are to feature a graduated color scheme from the base up to a height of about 50 m starting with a dark color and gradually getting lighter (green, grey-green, grey-blue, light grey). Pure white (snow-white) is not to be used.

The overhead cable pylons which are widely spaced (800–1,000m apart) overshadow the view and appear to box in the area. Owing to the characteristics of human perception, the WTs spaced 800–1,000m apart in the background appear smaller than the pylons. All the main observation positions which are relevant for the perception of the planned site were ascertained.

A thorough study of the area was carried out. It was found that in the area between 200 and 1,500m away, the WT site could be clearly seen from numerous positions. Some of the wind turbines appear overshadowed, especially by topographical features, forest areas and copses. Further away, although the site can still be seen, the individual WTs appear to be dominated by the landscape. The structural diversity, nearness to nature and beauty/nature of the landscape were taken into account for qualitative appraisal.

To balance the impacts and necessary compensatory measures, Nohl's model (1993) for the objective appraisal of landscape intervention was used. The areas from which the planned intervention could be fully perceived were defined as objectively aesthetically impaired. We distinguish between three zones:

- affects the immediate area; radius of influence r = 200m,
- extended radius of influence r = 1.5km, and
- low visual perceptibility.

The compensatory measures depend on the size of the area from which visual impairment is perceptible, and the aesthetic loss of landscape. Owing to the dimension of the wind turbines (with hub heights of 50–100m), aesthetic equalization (i.e. integration into the landscape) is impossible because of the high visibility and the nature of the wind turbines. Consequently, carrying out replacement measures is more urgent, although they will have to take another form (creation of a lake for amphibians and planting trees).

Using the example of wind energy, it is evident that the change in energy policy is by no means sufficient to effectively reduce interventions into nature and the landscape. As long as a trend towards fundamental energy-saving measures cannot be seen, the greater usage of water and wind energy makes little sense in view of its ecological and aesthetic impact on nature and the countryside and the generous subsidies required.

In Germany, the aesthetic qualities of landscape planning are enshrined in law (see Chapter 7.3). They include diversity, the nature of the landscape, and beauty, which are to be regarded in connection with the protection, preservation and development of certain parts of nature and the landscape (e.g. the designation of various protection areas).

In **municipal landscape planning**, aesthetic considerations are above all integrated into the planning of recreation areas.

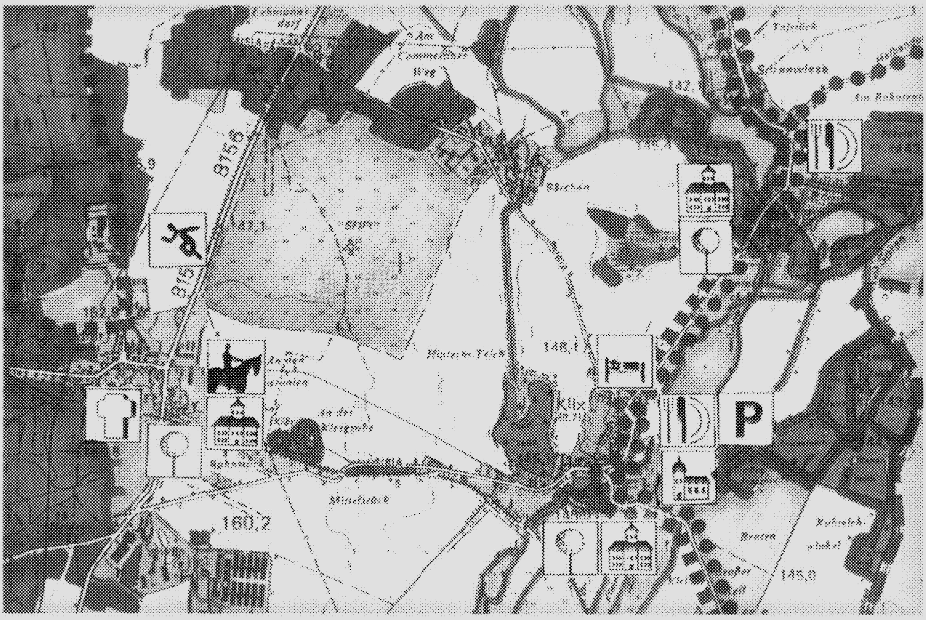


Figure 5.5-3: Landscape planning at the level of a village (Großdubrau, Saxony, Germany): Map "Landscape appearance and touristical infrastructure" (draft: Panse landscape architects 1999, unpubl.)

Aesthetic landscape appraisal was carried out for the village of Großdubrau in eastern Saxony (Germany) by way of example and by studying the landscape appearance and the infrastructure (Figure 5.5-3). For this purpose, elements of the infrastructure were recorded which:

- offer accommodation and catering for visitors (restaurants, hotels, campsites),
- are suitable as starting-points for walks (car-parks),
- enable active recreation (open-air swimming pools, fishing areas, bicycle hire, foot paths and cycle tracks),
- are of historical value (parks, castles, palaces, manors, churches, cemeteries, museums, monuments), and
- serve leisure activities (sports ground, bowling alley, playground).

Moreover, all the elements were shown which shape the landscape appearance of a natural area. The main measures proposed are:

- the preservation of diversity, nearness to nature and structure,
- the preservation of existing landscape elements and enhancing them with landscape structures suitable for recreation,
- the creation of landscape structures beneficial to gratification (e.g. by planting rows of trees and hedges, and renaturalizing streams), and
- surrounding outskirts of town and buildings which impair the landscape appearance with greenery.

Aesthetic analyses and appraisals are also carried out and aesthetically effective proposals made within development concepts for **village renewal**. The **local development concept** for Kleinwelka serves here as an example of aesthetic land and village design (Figure 5.5-4).

Maximum attention was paid to the main roads as well as the existing improved roads, parking-lots, foot paths and cycle tracks. We took into account both local conditions and the village's surroundings (including copses and buildings affecting the landscape's appearance). The proposed measures include village squares, individual buildings, fishponds and windbreak planting. By means of territorial reorganization schemes, an attempt is being made to introduce organic and integrated agriculture, with corresponding crop cultivation.

Surveys were conducted among all households concerning the main aspects of the village and the open landscape (transport, trade and industry, ecology, village design, community life). This was followed by a statistical evaluation and repeated discussion in community meetings and working parties in order to build up information and generate opinions. We organized dialogue between the local inhabitants and public agencies and authorities. Although the design ideas were drawn up by the landscape architect, they were then discussed by the inhabitants and prioritized together with the client (the local administration, see Chapter 7.12). The final version of the plan (comprising text and maps) contains aesthetic findings on the landscape and village. The implementation of the measures proposed is to be granted public subsidies.

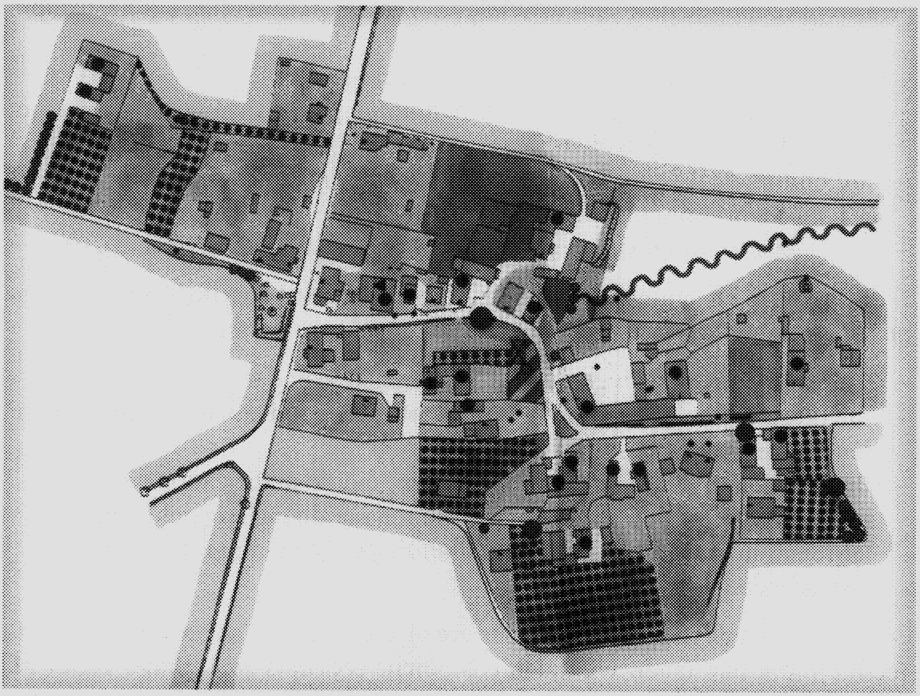


Figure 5.5-4: Village renewal planning for Lubachau (community Kleinwelka, Saxony, Germany) , including the settlement and its close vicinity (draft: Panse landscape architects 2000, unpubl.)

Landscape aesthetics includes both the beauty of landscape elements such as lakes, ponds, streams, avenues, clumps of trees, individual trees, and urban elements such as outskirts of town, roads, fences etc. Monotonization (the loss of diversity and individual features) runs counter to the principles of landscape beauty. At present, people are increasingly confronted with areas with reduced aesthetic gratification; examples include cleared land (containing no trees or bushes) and simplified agricultural landscapes. Beautiful countryside is increasingly being perceived as a commodity in short supply, which is why greater importance is being attached to it.

Consequently, the local development plan with an integrated greenery program entitled "The local recreation center of Commerau" (Saxony, Germany) is presented here as an example (Figure 5.5-5).

Using the instrument of binding development planning, aesthetic rules are stipulated in the development plan, and the program can be translated into practice by means of town-planning contracts.

The procedure for involving inhabitants and those with public responsibility in Germany is covered by legislation. Even preliminary drafts have to be put on display so that all the parties concerned can take note of them. This is followed by appraisal by the local council, which then reaches a decision. First of all, the ideas of the entrepreneur and the architect's basic design are needed.

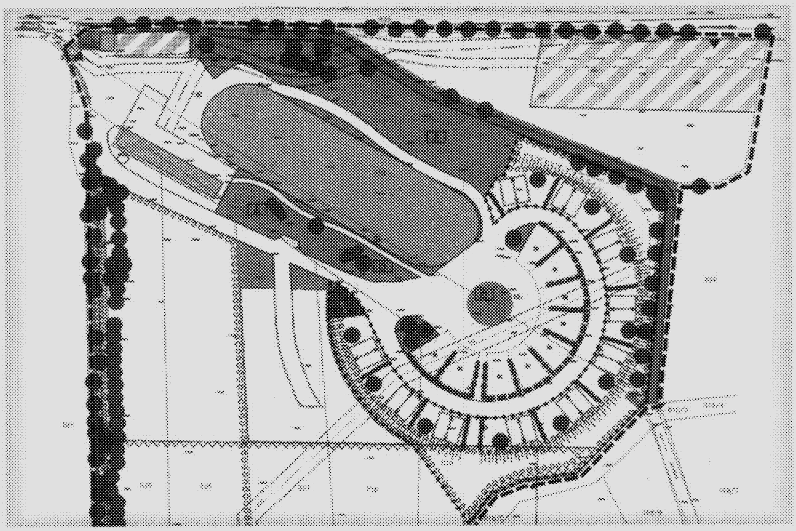


Figure 5.5-5: Formative plan for the Commerau local recreation center (Saxony, Germany). Among others, the swimming pool, buildings, campsites, trees, and meadows are depicted (draft: Panse landscape architects, unpubl.)

All those involved (the actors) such as neighbors, land owners, local authorities etc. were involved in drawing up the aesthetic design. One of the aims in Commerau is to reopen a currently disused open-air swimming pool so that it can be used economically, yet with high emphasis on a natural design. Ecologically sustainable recreation activities such as riding, cycling, charabanc rides and visits to the thousand years old town of Bautzen are to be offered for 40 families. Key design principles include limited development and construction typical of the area.

Visitors arrive via an avenue lined by chestnut trees. However, the area has also been given a striking design from a bird's eye view to ensure it is noticed by glider pilots and private aircraft. The surroundings consisting of ponds and types of construction typical of the neighboring villages, as well as the existing fields and meadows, are to be taken into account in the selection of plants, as is the location of the area on a flood plain. The shape of the roofs, the position of the buildings, and the choice of materials are to be derived from the local surroundings. Particular aspects of design could be emphasized during construction.

Modern-day landscape aesthetics are partly derived from German and European writing, painting, music and horticulture. In fact horticulture can (like the arts) be subdivided into stylistic eras (e.g. baroque and landscape gardens). Parks are artificial landscapes formed on the basis of aesthetic ideals resulting from their arrangement, and whose design reflects the conceptions of mankind and nature prevailing when they were laid out. They hence also preserve the historical view of the landscape (Figures 5.5-6 and 5.5-7).

Figure 5.5-6: Good landscape planning is characterized by the harmonious insertion of the work of art into the original landscape: Seußlitz Park (Saxony, Germany) (Photo: O. Bastian 1987)

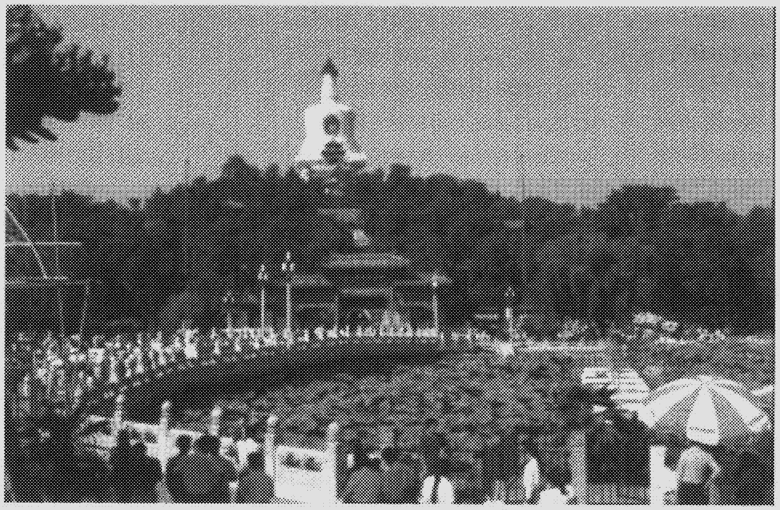


Figure 5.5-7: Parks are landscapes shaped according to aesthetical ideals. The White Pagoda in Peking (China) and its surrounding area is very attractive for visitors (Photo: O. Bastian 1994)

The fundamental design principles depend on mankind's view of his responsibilities in the world. When planning the **reconstruction of the 18th-century Königshain Park** (Figure 5.5-8), the first step in recreating its historical aesthetic appearance was to sift through the archives in search of information.

The lawn parterre had a steep slope on the palace side, emphasizing the central projection. The parterre was lined on either side by avenues with three rows of trees leading to ornamental pillars. The trees (limes) were not cut and had low scrub.

The park, an artificial landscape with lines of sight extending from the palace to the church tower, as well as the transition to the landscape part, the elevated Belvedere facing towards the Giant Mountains (in Poland and the Czech Republic), are some of the premises for the maintenance of these historical grounds. The tree register was used to reconstruct historical rows of trees. Behind the avenues, the garden is surrounded by a trimmed hedge. To the north, an alcove hallway has been re-established. When designing the parterre, documents from digital surveys were used. It was only thanks to the lime trees and herbaceous perennials planted as well as the paths with their characteristic gravel surfacing that the historical rococo garden was made spatially perceptible to visitors again.

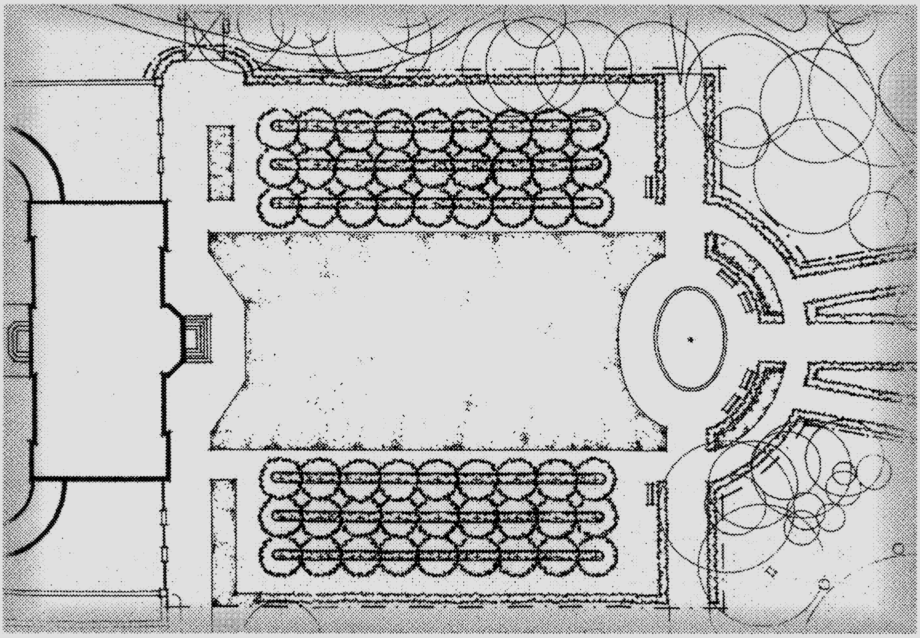


Figure 5.5-8: The plan of the Königshain Park (Saxony, Germany) (draft: Panse landscape architects 1998, unpubl.)

Chapter 6

Investigation methods / tools

J. Löffler, U. Steinhardt, M. Volk, U. Walz

6.1 Landscape ecological mapping

6.1.1 Principles

Maps are one result of landscape ecological analyses showing the spatial arrangement of landscape complexes (see Chapter 2.2). With regard to different spatial dimensions of investigation **landscape ecological maps** vary in scale and content. Moreover, mapping methods, tools and techniques are individually transposed according to different approaches. Practical threats of landscape ecological research as well as needs in application necessitate the effort of maps as investigation, presentation and communication instruments, since:

- the results demonstrated in maps represent a spatial scale-bound message that can be used for multifarious purposes,
- the statements being illustrated are more or less quantitative, and
- synthesized landscape units are characterized in substance reducing and qualifying the significance of boarder lines between the single units (Leser 1997).

Basically, landscape complexes are such complex spatial-temporal phenomena that landscape units like ecotopes, ecochores, etc. cannot be illustrated on the whole within a landscape ecological map. Thus, information representing the character of the single landscape units is reduced according to single landscape elements (e.g. maps of spatial soil texture variability) or landscape components (e.g. maps of distribution of soil types). But the most

O. Bastian and U. Steinhardt (eds.), Development and Perspectives of Landscape Ecology, 257-306.

common results of landscape ecological investigations are maps of partial landscape complexes showing a relative high level of integration and aggregation (e.g. maps of distribution of pedotope types). Additionally, special maps of landscape ecological processes and functioning features are produced (e.g. maps of soil moisture variability). Within a landscape ecological analysis all those layers of different partial landscape complexes are analyzed as to spatial interactions and correlations between them. Landscape ecological mapping is therefore linked with the following problems of analyzing and synthesizing spatial landscape units on the basis of landscape complexes: The synthesis of landscape units on a high level of integration by aggregating several attributes from the basis of partial landscape complexes leads to a reduction of detailed information. Thus, the result presented in conventional maps does not enable the user to go back to the basic data (Finke 1994). However, we can scrutinize the sense of such a synthetic map representing the landscape complex: What is the higher level of a landscape ecological message contrary to a catalogue of maps presenting partial landscape complexes? If we believed that a landscape complex represents a higher level of integration maps of landscape complexes should illustrate more than the sum of information of all those maps of partial landscape complexes (Egler 1942, Smuts 1926).

Two different approaches have been practiced for the mapping of landscape ecological units. At first, landscape is analyzed from a holistic point of view, **deductively** mapping the boundaries between several units and defining those units by means of structure and process attributes afterwards. On the other hand, landscape is composed by single units **inductively** analyzed within their partial complexes building up spatial arrangements of landscape units. An important methodological difference between those two approaches lies in the philosophy of the existence of landscape units a priori (in the first case) and the theoretical construction of landscape units (in the second case) that are the result of concrete methodological conceptions grouping single information layers into a new pattern of organization.

6.1.2 Development of landscape ecological mapping approaches

Landscape ecological mapping has a long tradition in Germany. The first of such maps showing the spatial arrangement of ecotopes has been given by Troll (1943). Continuing with the "Definition of nature areas in Germany" (Naturräumliche Gliederung Deutschlands) (Meynen and Schmithüsen 1953-62, see Chapter 1.2.3) above all, mapping was concentrated on investigations of large areas. Within this context landscape was regarded as a holistic structural phenomenon that was analyzed as to a **qualitative approach** primary mapping landforms with interest in substrate and relief conditions presumed as being the major factors influencing landscape ecological processes. This strongly deductive way of mapping comparable large areas was accompanied by small scale investigations using vegetation, soil and water dynamics as well as micro-climatic attributes (Paffen 1953). In this way, selected landscape ecological features have been used to describe the landscape structure in its spatial regularity. Further advancements of mapping principles have been given as a qualitative and analytical method to define landscape units by means of an inductive aggregation of landscape ecological attributes within a hierarchy system of landscape components and partial landscape complexes (Czajka 1965, Schmithüsen 1967, Troll 1950). Examples characterizing different landscape units in front of a hierarchical frame came from Dierschke (1969), Klink (1964, 1966), Neef et al. (1961) and Werner (1969). Especially the descriptive analyses of larger areas and spatial characterization of ecotopes and ecotope mosaics as to the **catena principle** (Haase 1961, see Chapter 2.6) by means of integrating several landscape components and partial landscape complexes with regard to the situation in different landscapes have been clear and illustrative (Klink 1994). Significant scientific progress during these early approaches in landscape ecological mapping has been established by integrating quantitative aspects into the hierarchical characterization of landscape units (Haase 1964, 1967, Neef 1963, 1967, Richter 1967, Richter and Barsch 1978, Schmidt 1973). Based upon this **quantitative approach** several landscape ecological publications dealt with functional characterization of landscape units for application in landscape planning (Finke 1971, Schreiber 1969, 1985).

From the beginning of the 1980s landscape analysis has been practiced within a **systems approach**. Remarkable further advancements have been given by different authors (Klug and Lang 1983, Lang 1982, Leser 1984, Mosimann 1984a) based upon the quantitative landscape ecological principles described above. This concept can be characterized by a functional analysis of landscape units. Within the topological dimension extensive measurements led to detailed functional process attributes that were used to define ecotopes on the fundamentals of **landscape ecological complex analysis** (see Chapter 3.4). Those landscape ecological maps show a spatial arrangement of structural defined ecotopes, in addition described by means of catalogues of landscape ecological attributes (Mosimann 1985). Over and above that, partial functional complexes of the landscape have been balanced.

Based upon the problem of this empirical level of landscape analyses with its technical and financial limits a process-orientated approach was needed for the rational mapping of larger areas. From the idea that landscape complexes could be mapped by using standard methods and classification principles the **"Handbook and guidance for landscape ecological map-**

ping" (the so-called **GÖK 25 concept**) has been published (Leser and Klink 1988, see Chapter 1.2.5). It has been stated that landscape units should be analyzed as to structural attributes such as slope gradient, soil texture, vegetation type etc. following a strict classification of those structural landscape components. Landscape ecological maps should be given for different landscapes of Germany on the basis of a defined map scale (1:25,000) enabling a scientific comparison between those areas and a standardized evaluation of single landscape potentials and functions. Mosimann (1990) has criticized that this principle was missing a hierarchy, and he proposed a concept for a process classification of ecotopes that has been adopted by Duttmann (1993) within his digital landscape ecological mapping approach. A similar process orientated concept has been given by Zepp (1991) integrating structure and process attributes for a characterization of several landscape ecological process constellations. As has been shown by Hütter (1996) landscape ecological **process mapping** can lead to a detailed illustration of spatial matter and water balance phenomena of the landscape including different human influences like agricultural land use intensities, different types of forestry and urban sealing etc. (Figure 6.1-3). All those mapping approaches within the topological dimension have been based upon field analyses of structural landscape elements, components and partial landscape complexes and derived from syntheses of process characterization.

Landscape ecological mapping in **different landscapes** cannot always follow the same integral approach of correlations between structural attributes being mapped and process attributes being diverted. In extreme climates of arid, alpine and arctic landscapes we often find completely different interactions of landscape elements within the ecosystems and measurements, additionally, mapping routines are not easy to transfer from other regions like Central Europe (Leser 1986). E.g., for the high mountains of Norway it has been proved that energetic variability is the superior influence on ecosystem functioning and therefore usually defines landscape units (Löffler and Wundram 2001, Figures 6.1-4 and 6.1-5).

Currently, maps within the topological dimension can be considered as important for applied sciences, because they represent the needs "at the spot" where major decisions e.g. in landscape planning are felt (Leser 1997). Early stages of theoretical and methodological development in chorological approaches have already been given by Barsch (1969), Glawion (1985), Haase (1964), Neef (1963) and Schmidt (1973). In principle, all chorological mapping approaches can be characterized by principles of transforming single structural landscape components into a higher level of spatial organization (Kaulfuß 1973). But the main problem of chorological landscape ecological mapping has been found to be the lack of process characterization of ecochores, although this problem has been appointed to by Haase (1979) who already requested to put more emphasis on chorological process analysis of landscape functioning and dynamics (Leser 1997).

Thus, **chorological landscape ecological mapping** has led to the fact that landscape units within the chorological dimension are mostly corresponding with the geological and geomorphological genesis of the landscape structures like larger relief formations, substrates or soils. Those landscape structures have been regarded as recently traced by the former landscape processes only being influenced and modified by processes of land use, vegetation dynamics, etc. (Billwitz 1997). An example of consequent classification stages and mapping principles of structural ecochores is given by Syrbe (2001, Figure 6.1-7). Additionally, a combined approach using inductive aggregation of process analyses and deductive mapping methods has been applied by Löffler and Wundram (2001) for the Central Norwegian mountains. Based upon long-term measurements of temperatures within and between several catchment areas chorological process characterization has been conducted (Figures 6.1-4 and 6.1-7).

The further development is characterized by the **landscape ecological analysis routines** (Zepp and Müller 1999). Several experts have integrated methods into a complex tool for the deduction of landscape ecological process attributes. Moreover, digital data organization is proposed.

6.1.3 Examples of topological mapping approaches

Schultz and Finch (1996) have developed a combined **classification of coastal landscapes** of North-Western Germany on the basis of the red data book of endangered biotope types (Riecken et al. 1994) by means of **vegetation and fauna features** (Figure 6.1-1). It has been shown that the spatial distribution of spiders (Araneae) is closely related to the spatial arrangement of abiotic landscape elements. Especially, soil moisture and micro-climatic conditions proved to have a superior influence on animal distribution (Martin 1991). Different preferences of many species lead to a precise delineation of spatial mosaics in animal distribution (Hänggi et al. 1995). From this point of view mapping of characteristic species that show a significant higher persistence and abundance in specific types of landscape units and are considered to find their environmental conditions more often and more frequently than in any others, can be regarded as a highly integrated structural landscape ecological method.

Based upon the **GÖK concept** (Leser and Klink 1988) different landscape ecological mapping projects have been conducted. Duttmann (1993) dealt with a characteristic quarternary landscape in Northern Germany dominated by agricultural land use patterns on loess substrates. Process attributes like soil moisture regime, soil and humus temperature or biotic activity have been adopted by particular field measurements. Additionally, soil analyses have been carried out at representative sites. The data have been aggregated into types of landscape components for the classification of partial complexes. The structure of the resulting GIS-database has been organized according to the ecotope classification hierarchy (Mosimann 1990). This allows a standardized synthesis of spatial landscape units based upon several process attributes.

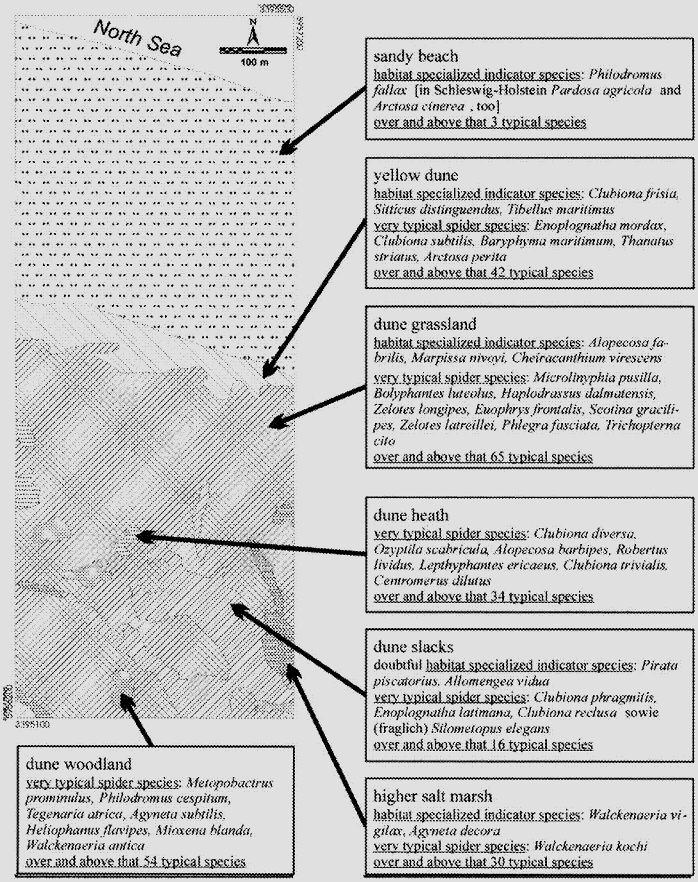


Figure 6.1-1: A species list of spiders (Araneae) derived from all regional data available and corrected by an expert system, arranged according to the spatial mosaic of phytotope types (after Drachenfels 1994). For bioindication purposes habitat specialized indicator species and characteristic species of the coastal biotopes are established. The map shows a part of the coastal dune island Baltrum in the North Sea (draft and design: Finch 2001)

The digital map comprises of spatial geometric attributes as well as structure and process attributes in substance. The original **digital landscape ecological map** by Duttmann (1993) consists of approximately 3000 smallest common geometries obtained by intersecting the individual information layers aggregated into 125 basic types of ecotopes (Figure 6.1-2). The pros of this mapping approach lie in

- the organization of basic landscape ecological data that can be made available from the data basis or completed by new information at any time,
- the corresponding availability of arbitrarily chosen spatial information and the reprint of different information layers on maps, and
- the resulting flexibility within the scope of application in e.g. landscape evaluation or landscape planning, etc.

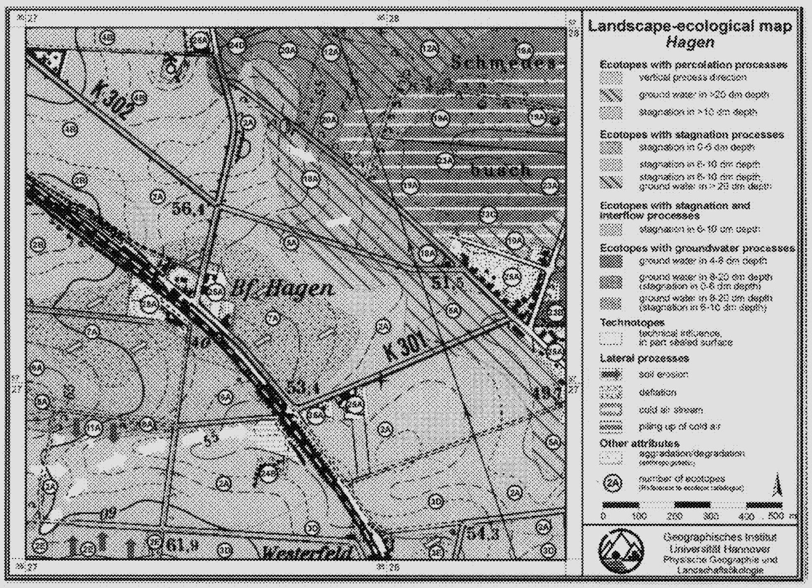


Figure 6.1-2: Subset of a landscape ecological map showing ecotopes in the quarternary loess lowland near the village Hagen in Lower Saxony (Germany) with superior water balance features derived from complex process measurements and deductions (Duttmann 1993)

Hütter (1996) followed the GÖK concept and the conventional mapping principles, but also integrated a **landscape ecological process characterization** based upon nutrient and water balance attributes of the ecosystems. Process attributes like soil nutrient status, cation exchange capacity and several structural soil attributes have been adopted to by particular laboratory analyses. Relief attributes have been used as structural landscape elements for the spatial delimitation of nutrient and water balance units. Moreover, the relief has been analyzed with regard to energetic attributes like radiation input, cold air distribution, wind conditions and correlated depositions. For the urban settlements sealing indexes have been mapped by remote sensing

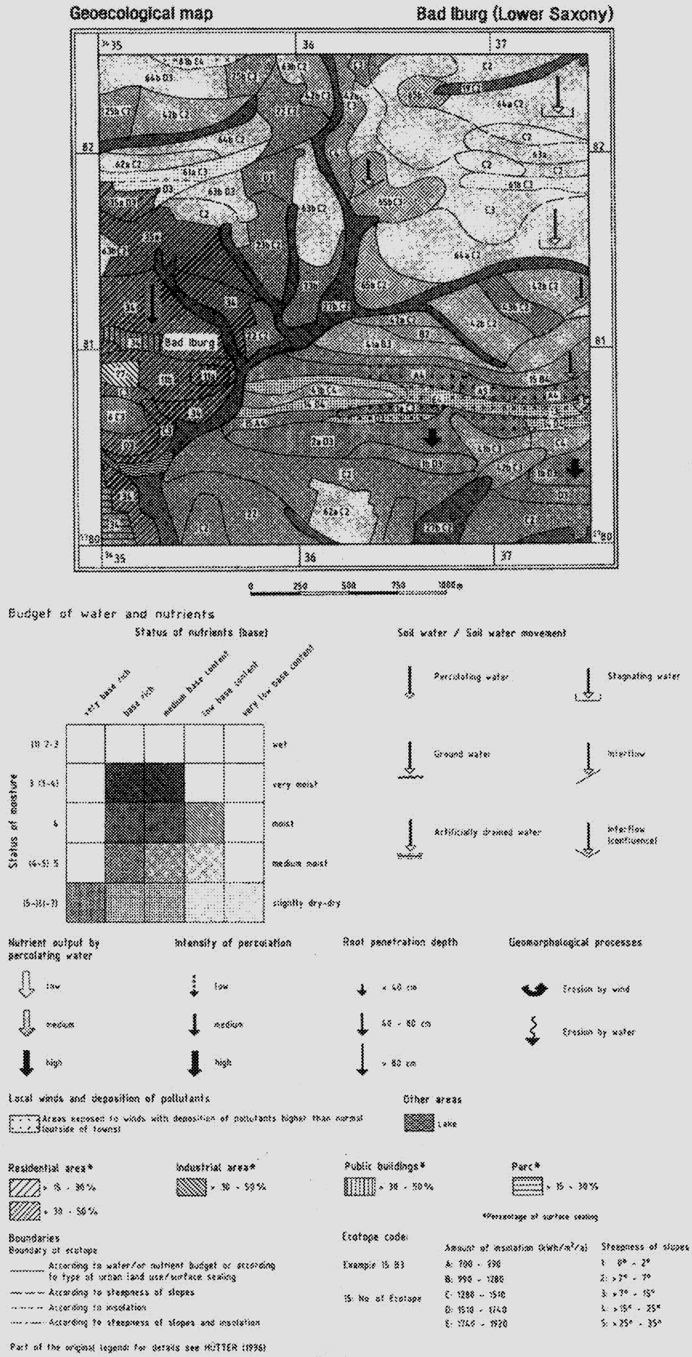


Figure 6.1-3: Landscape ecological map showing ecotopes with superior nutrient and water balance features derived from complex process deductions (Hütter, 1996). The map shows a cut from the middle mountain landscape surrounding the village Bad Iburg in Lower Saxony)

and additional field investigations. From those attributes technotopes have been characterized. Streams have been analyzed according to structural attributes of stream cross-section, vegetation patterns of stream banks and physical and chemical water analyses.

This map (Figure 6.1-3) shows that ecotopes are intensively dominated by the human influences on processes within the matter and water balance. This can be visualized by means of complex nutrient attributes that are determined by e.g. acid deposition in forests or nutrient input by fertilization. Moreover, spatial differentiation of surface sealing determined water balance is demonstrated. Thus, according to Klink (1994) this approach represents a new kind of map type for a versatile application in nature conservation, landscape planning, agriculture and forestry, and other spatial land use purposes.

Correlations between vegetation cover and soil distribution, humus forms and water balance as well as snow cover and air, surface and soil temperature regimes have been analyzed showing a very large scaled and complex spatial organization within the high mountains of Vågå/Oppland. The theoretical and methodological framework of the project is derived from the **landscape ecological complex analysis** (see Chapter 3.4) and its variations due to technical and principle methodical challenges in this **high mountain landscape** (Köhler et al. 1994, Löffler 1998, Löffler and Wundram 2001).

The results have shown that the local climate has to be regarded as the superior factor in these mountain ecosystems for physical, chemical and biotic process determination (Löffler 2000). Climatic regularities deduced from measured data have been quantified with regard to their scale in ecosystem processes. In this way, qualitative and quantitative modeling of interrelations between spatial ecosystem compartments has been possible (Figure 6.1-4). The hierarchy of the process-oriented classification of ecotopes has been defined by types of temperature dynamics (Figure 6.1-5). Daily and annual temperature dynamic is demonstrated by means of thermoisopleth-diagrams. Thus, the map shows the spatial arrangement of ecotopes defined by complex process attributes.

	temperature type	code	duration of daily means [in months]		duration of frost [in months]	annual amplitude [K]	duration of daily maximum [in months]			
			> 10°C	> 5°C			> 25°C	> 13°C	< -1°C	< -13°C
air	extreme-cold	ex-cold	never	<3	>6	>45	never	<1	>6	<1
air	persistant cold	per-cold	never	<3	>6	<40	never	<1	>6	never
air	moderate-cold	mod-cold	never	<3	<6	<40	never	>1	<6	never
air	extreme-cool (eutherm)	ex-cool-eu	>1	>3	<6	>45	<1	<3	<6	<1
air	extreme-cool	ex-cool	>1	>3	<6	>45	never	<3	<6	<1
air	moderate-cool	mod-cool	>1	>3	never	<40	never	<3	<3	never
air	eutherm-cool	eu-cool	>1	>3	<6	>40	<1	>3	<6	never
surface	persistant-cold	per-cold	never	<3	>6	<30	never	<1	>6	never
surface	moderate-cold	mod-cold	never	<3	<6	<30	never	<1	<6	never
surface	extreme-cool	ex-cool	>1	>3	<6	>40	<1	<3	<6	never
surface	extreme-cool (moderate)	ex-cool-mod	>1	>3	<6	>30	never	<3	>3	never
surface	extreme-cool (eutherm)	ex-cool-eu	>1	>3	never	>45	>1	>3	never	never
surface	moderate-cool	mod-cool	>1	>3	<1	>25	never	>1	never	never
soil	extreme-cold	ex-cold	never	<3	>6	>20	never	never	>6	never
soil	persistant cold	per-cold	never	<1	>6	<20	never	never	>6	never
soil	moderate-cold	mod-cold	never	<3	<6	<20	never	never	>3	never
soil	extreme-cool	ex-cool	>1	>3	<6	>30	never	<1	<6	never
soil	moderate-cool	mod-cool	never	>3	never	<15	never	never	never	never
soil	moderate-cool (extreme)	mod-cool-ex	never	>3	<3	<20	never	never	>1	never

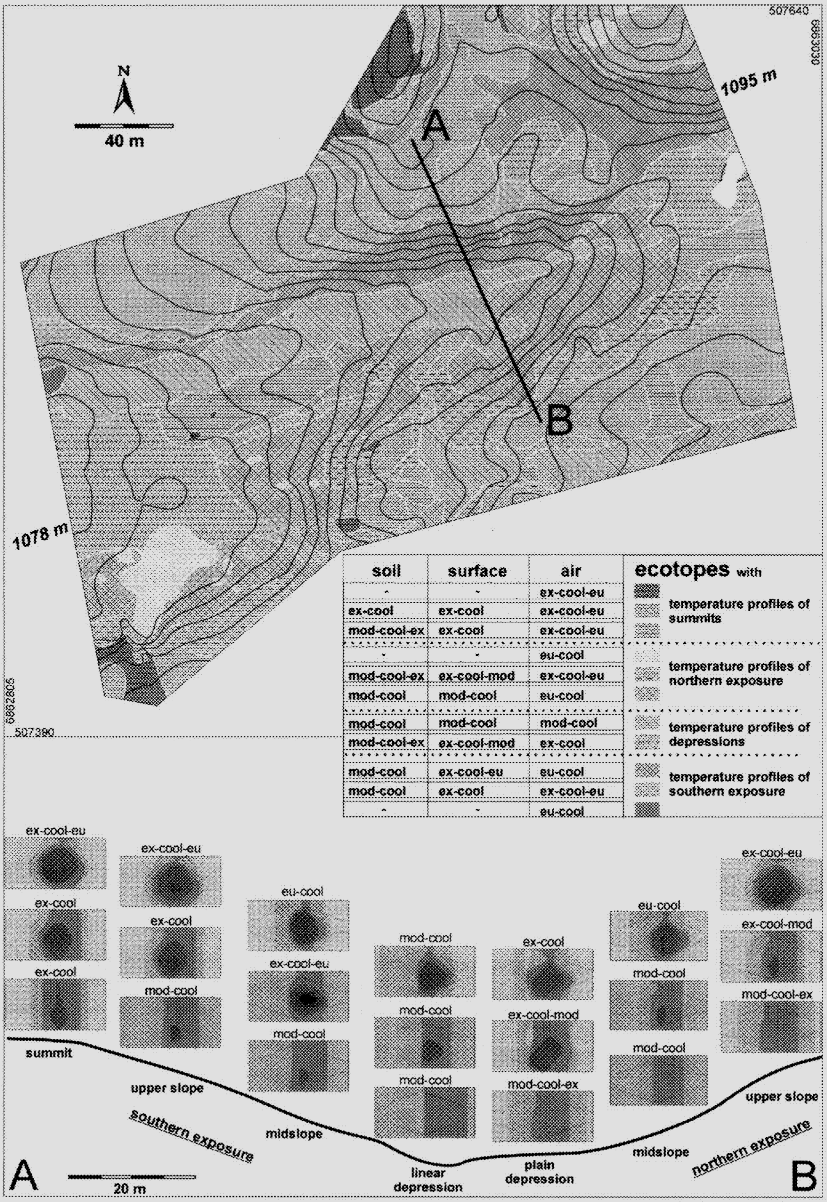


Figure 6.1-4: Landscape ecological map showing ecotopes with superior energy balance features derived from temperature measurements (Löffler and Wundram 2001). The map contains a subset from the Central Norwegian mountain landscape as an example of a catchment area in the low alpine belt (legend is given on page 265)

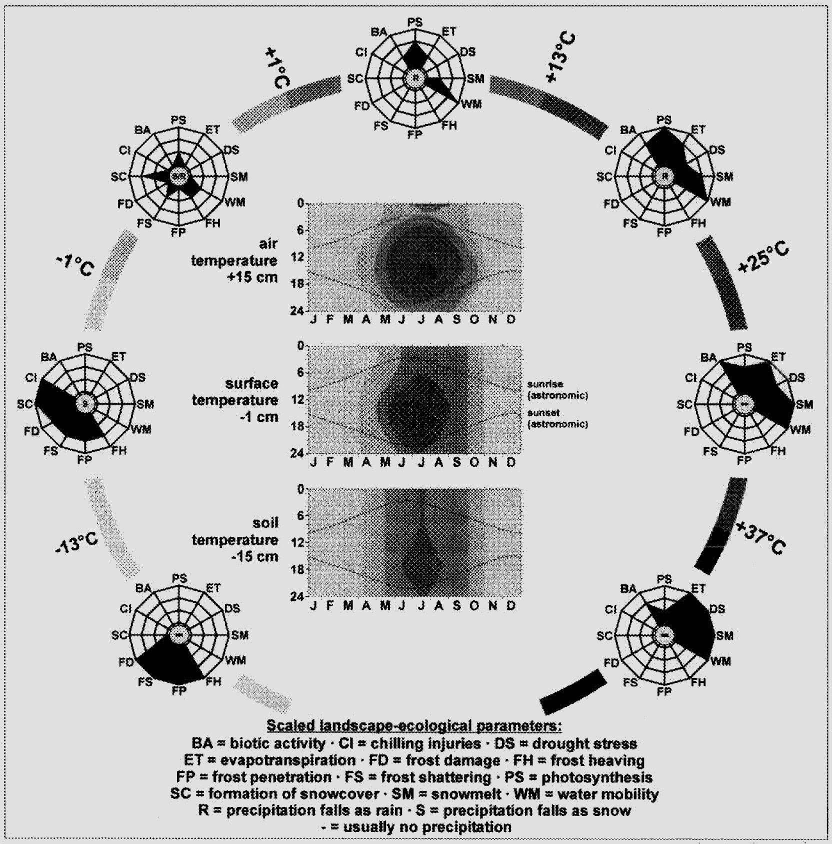


Figure 6.1-5: Complex scheme of systematic scaling of temperatures according to their influence on ecosystem functioning. A triple of air-, surface- and soil-thermoisopleth-diagrams shows daily and annual changes of seven different ranges of temperatures with similar ecological values for a particular site. Those temperature ranges subdividing the outer circle of the diagram into 7 circle segments are grouped according to literature data, own investigations and theoretical considerations on 13 landscape ecological process attributes. Processes like photosynthesis, evapotranspiration, drought stress etc. are in their turn scaled on the individual axes within the small net circles according to their ecological influence under those temperature conditions (from the inside to the outside: no, little, moderate, high and extreme influence). (legend is given on page 265)

6.1.4 Examples of chorological mapping approaches

Syrbe (1999b) has given methodological **principles for chorological mappings** (Figure 6.1-6). With five fundamental stages that can be varied according to different scales and intensions of the mapping approach. Compared with the topological mapping approach not just single attributes but already types of attributes are being grouped. The chorological method is complicated, because landscape units are defined by a very high abstraction on different parallel levels. The result is often an idealized synthesis of real structures in the way that they are often not detailed enough for special applications (see Chapter 2.2).

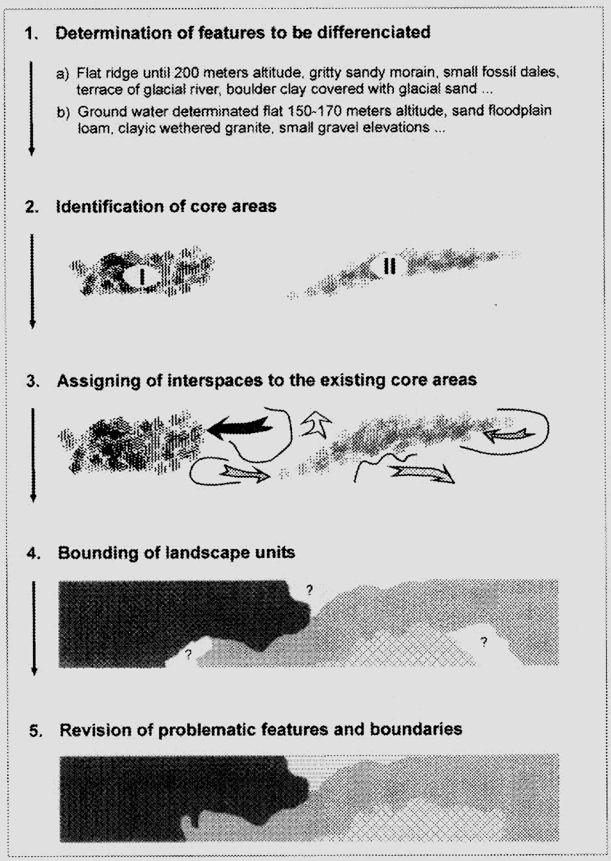
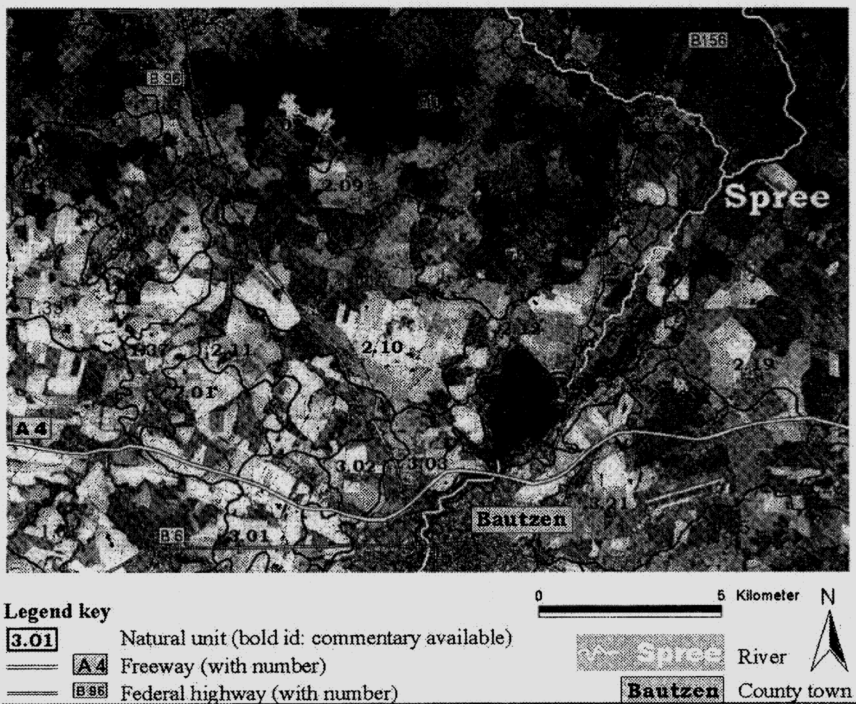


Figure 6.1-6: Methodological guidelines for the landscape ecological mapping of ecochores (after Syrbe 1999a,b)

As an example Figure 6.1-7 shows the boundaries of heterogeneous **micro-geochores**. Each microgeochore has been described by structural attributes that have been found to define a transmission of emergence. Those structural attributes are based upon general genetic relief and substrate. Different land use patterns are aggregated within the ecochores, and they are specified by soil features. Spatial analyses of such theoretical landscape units has to follow the underlying guidelines very strictly. Otherwise, the results are completely subjective. The chorological approach in the Central Norwegian high mountains studies (Figure 6.1-8) is based upon the ecotope mapping concept that has been adopted to the whole mountain massive above the timber line by means of vegetation and relief mapping. From the complex spatial arrangement of ecotope mosaics ecochores have been derived and characterized by functional air temperature attributes. In this way, a strict inductive transition of emergence has been proved. Over and above that, those air temperature attributes have been found to be grouped into two general categories comprising larger areas as similar ecochores based upon their spatial arrangement. These two spatial units define the altitudinal belts as a characteristic process determined ecochore mosaics.



Id-code	individual name	type
1.35	Doberschütz clay plate	plate on granite with dystic gleysols /gleyic cambisols in dry upland
1.36	Wetro hilly area	plate of glacial sand with cambisols / podzols in dry upland
1.37	Sollschwitz-Luga Schwarzwasser valley	Bottom valley on solid rock with gleysols / fluvisols in dry upland
2.01	Bolbritz loess plate	plate with thin loess and typical / gleyic luvisols in humid upland
2.07	Floodplain of Kleine Spree near Milkel	Floodplain with gleysols in humid lowland
2.08	Hahnenberg moraine complex	low ridge of glacial material with cambisols / podzols in humid upland
2.09	Luppa hollow	Floodplain terrace with gleysols in medium humid lowland
2.10	Radibor loess plate	plate with thin loess and typical / gleyic luvisols in medium humid upland

Figure 6.1-7: Landscape ecological map (draft and design: Syrbe 2001) showing a subset from the Upper Lusatian loess region around the town of Bautzen in the south up to the heath and pond landscape in the north (Saxony, Germany)

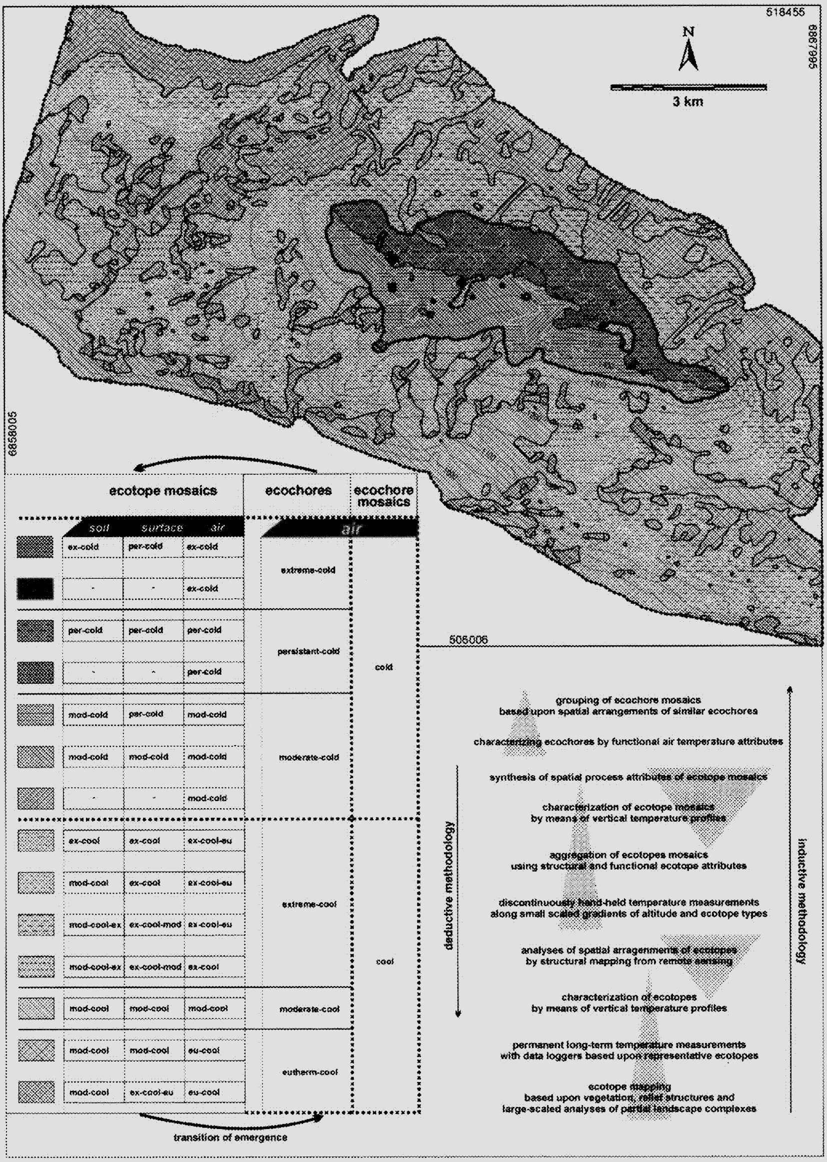


Figure 6.1-8: Landscape ecological map showing ecochores with superior energy balance features derived from temperature measurements (Löffler and Wundram 2001). The map represents a subset from the Central Norwegian mountain landscape (legend see Figures 6.1-4 or 6.1-5)

6.1.5 Perspectives of landscape ecological mapping approaches

It has been shown that landscape ecological maps vary in substance, scale and methodology according to the different approaches being applied, different landscapes investigated, and different geographical dimensions conducted to. In general, all maps demonstrated above are based upon an **integrative definition of the landscape complex** and follow a **strict theoretical hierarchy** that finds its expression within the classification of landscape units mapped. The scientific and application challenge can be seen in the tremendous knowledge about landscape functioning and dynamic in different spatial dimensions, if such approaches would be transposed into other regions. Especially process-oriented mapping principles have overcome technical and methodological problems of an adequate and sufficiently parameterization of water, matter and energy fluxes. Facing the environmental problems of the future landscape ecology will have to develop the mapping concepts for attaining information, knowledge and awareness about ecosystems of different structure, functioning and dynamics.

The **cons of** all presented **landscape ecological mapping approaches** are the final analogue reprints of those synthetic maps concerning their conventional use. The complexity and diversity of single landscape units cannot be visualized clearly, and users are not able to handle the single information layers within their spatial arrangement. Those maps usually consist of a large number of numeric identifiers corresponding with the legend that is represented by a tremendous catalogue of landscape units. Thus, the map itself has to be regarded as (just) being a scientific product on a very complex theoretical and methodological level.

However, all of those maps have been produced for scientific purposes and more or less follow a random approach. It remains to be seen if such landscape ecological maps are being used for any application. A comparison and evaluation of different landscapes will not be possible until similar methods are used for landscape analyses and similar classification hierarchies are adopted to the definition of landscape complexes. Thus, standards for landscape analyses (e.g. Bastian and Schreiber 1999, Zepp and Müller 1999) are necessary and have to be developed within the frame of the process-oriented investigation approach in different spatial and temporal dimensions. Nevertheless, the landscape ecological map per se cannot be developed since we define the landscape complexes by means of several structures and processes.

6.2 Landscape information systems

6.2.1 Introduction

Human intervention causes rapid changes in the environment. With this in mind, it is important to develop methods, which enable us to quickly assess the most varied spatial landscapes with regard to the operability of the landscape balance. Assessment of the development of this balance over longer periods of time is also important. The important tasks for landscape ecology at present are the recording and assessment of natural resources, examination into the effects of human intervention and pollution resulting from human activity and long-term observation of the state of the environment. These tasks can be carried out with the help of relevant, comparative indicators, which have been compiled over long periods of time for larger areas of land. Moreover, convincing visual presentation of effects on ecology and their causes will become ever more important for decision making by political bodies and citizen's organizations.

Use of Geographic Information Systems (GIS) and remote sensing (see Chapter 6.3) is becoming more and more important for the tasks listed above. These technologies provide tools and methods which help in assessing the consequences that can result from certain actions and decisions quickly. This means it is possible to be flexible when reacting to changing demands. One indeed can no longer imagine carrying out basic research in the field of landscape ecology without the help of GIS to analyze the sometimes vast amount of data. Complex ecological methods and mathematical evaluation and calculation processes which could not be applied when using an analogue approach, can now be used when working with a GIS.

6.2.2 What are Geographic Information Systems?

Geographic Information Systems (GIS) are defined as a computer aided system made up of hardware, software, data and applications. Using the system it is possible to record, edit, save, reorganize, model and analyze spatial data digitally as well as present it alpha-numerically and graphically (Bill and Fritsch 1991). "Geographic" means correlating data geographically, e.g. into Gauss-Krüger references or as UTM coordinates (georeferenced data). This allows to combine different data sources and to derive and model new information from existing spatial basic data.

With regard to the data structure, one has to differ between vector- and grid-systems. Most software programs today, however, combine both in a "hybrid" GIS. This way it is possible to integrate remote sensing data (as raster data) as an important data source into GIS (see Chapter 6.3). Software like Arc/Info, SPANS etc. are often referred to as a GIS but actually only form a part of it.

"Depending on the specific field of application GIS can be developed for special purposes and "filled-in" with data and queries. In this sense a Landscape Information System (LIS) is an environmental information system that is used to record data concerning abiotic and biotic natural resources as well as land use information. In addition, it can be used to simulate and document spatial environmental processes, which occur rapidly as well as over long periods" (Werder 1998).

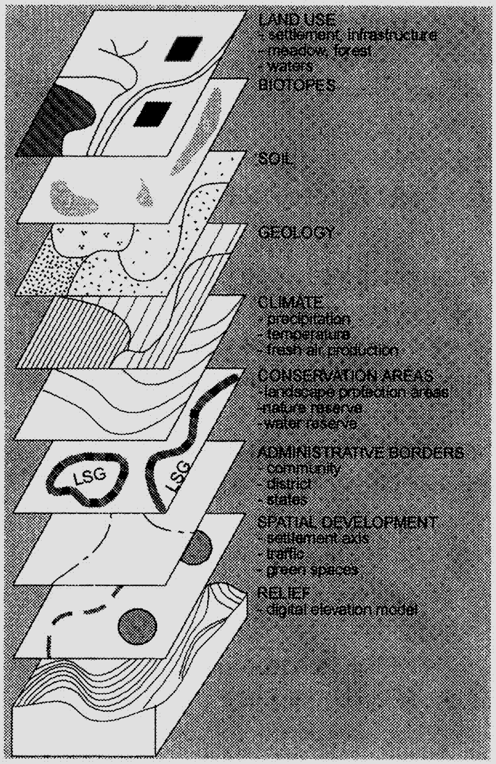


Figure 6.2-1: Thematic layers of a GIS

In order to organize geometric and thematic data in a GIS for consequent analysis and modeling, there are **thematic layers** into which the data can be input (Figure 6.2-1). Hettner (1932) was the first who described this layered structure in his regional scheme: "...if one imagines the earth's surface to be a map and all properties of nature, those of human life, inner structure, form of the surface and composition of the earth's solid crust, lakes, rivers and waters, air pressure and wind, air temperature, humidity and precipitation, vegetation and the animal world, nations and states, traffic and transport, economic relations and so on each to be a separate layer spread out over the map, one can clearly see everything that is part of geography. The human ability of comprehension is, however, not sufficient to take all of this in at once. If you look from the side and move your eyes up and down you can see each individual phenomenon in succession; if you look down from above and imagine the layers to be transparent, you can only see one point on the earth or maybe a limited area but you see all the phenomena found there at the same time." This model is very suitable for showing how the separate spatial levels can be combined with one another and new geometries and attributes can be derived from them. However, GIS functions can be used to generate the separate layers themselves. GIS allow to edit geometries and attributes when erroneous input data needs to be corrected.

In addition to spatial information in the data levels topographical and thematic information about objects is saved in a GIS database (Goepfert 1987). This gives the **objects properties**, which can be processed by the GIS (Bartelme 1989)

- by using information on the geometry of the objects (point, arc or polygon) and the respective reference system it is possible to assess the geometric properties such as location or extent of the objects. In the same way it is possible to assess topological properties such as neighborhood relationships and overlapping, etc.,
- qualitative and quantitative object characteristics (e.g. soil type of a plot, number of inhabitants in a town district, readings made by a weather station), and
- names, object labels (e.g. street names).

These properties are essential for the extensive analysis and modeling functions of a GIS.

In the analytical part of the system thematic levels (layers) are combined, and this leads to the creation of completely new geometries. The various layers can be weighted differently by using, link matrices, for example. It is also possible to include time segments (chronological layers) within a GIS. Integration of the third dimension allows to analyze vertical stratification (Laurini and Thompson 1992).

The functions in the following list are amongst the **most important basic functions**:

- geometric data query,
- measuring, counting and calculating,
- generation of zones or buffer zones,
- combining of areas,

- interpolation and abstraction,
- statistical functions,
- neighborhood and connectivity analysis,
- network functions,
- picture editing functions, and
- terrain modeling functions.

It should be emphasized that working with the different levels in a GIS is not about creating a descriptive presentation of the landscape, such as generating a map using the data available. What it is about is analyzing the interrelations between the layers and the effects they have on one another. Spatial-statistical analysis using a GIS can help to verify the connections between processes and effects and uncover connections that are not clearly visible at first. Using GIS enables to go beyond statistical observation of the landscape and actually recognize dynamic processes (Vogel and Blaschke 1996).

All "classic" sources of knowledge and methods of recording can be used as **sources** for **thematic data**. Analogue maps can both be scanned and transferred onto a digital grid followed by geocoding or manually digitized as vectors. A manual or (semi-)automatic transformation from raster to vector data is possible to. Remote sensing by satellite has, for years, been one of the most important digital data sources on the earth's surface, particularly for extensive areas (see Chapter 6.3).

At present a considerable amount of spatial basic data is available in digital form (Table 6.2-1). It is essential to set up meta-information systems, which have information about the environmental data available and also make it easy to find (Table 6.2-2).

Table 6.2-1: Selected data sources of land use

name	area	scale	contents
CORINE Land Cover	Germany and all EU-countries	1:100,000, (plots > 25 ha)	44 classes grouped in a 3-level hierarchy: artificial surfaces, agricultural, forest and semi-natural areas, wetlands, water bodies
ATKIS[1)]	Federal Republic of Germany	1:25,000	settlement, green spaces, extraction areas, traffic areas, water bodies, vegetation, administrative boundaries
Biotope type mapping	East Germany and Schleswig-Holstein	1:10,000	very detailed nomenclature with 8 main classes: water bodies, marsh and moor, pastures, fallow land, heathland, trees and hedges, woods and forests, agriculture, settlements, roads and green spaces

1) official topographic-cartographic information system

Those who are uncritical in the way they use GIS are often justifiably criticized. It has to be mentioned that in practice, planners working in an analogue way can also work carelessly and uncritically. They also have information, which is inexact and was compiled using varying standards and they often bring in additional subjective influences in as well. Using a GIS to combine different data levels at least eliminates "geometric" subjectivity unlike the simple method for integration. Working with spatial data possible **causes of errors** are the inaccuracies resulting from digitalization, the varying standards used for input data and processing errors caused by users and software algorithms. There is a cumulative effect, which means that number of errors increases each time the data is combined.

Table 6.2-2: Examples of meta-information systems in Germany

The **German Environmental Information Network** (GEIN = Umweltinformationsnetz Deutschland) acquires information that is spread around the Web pages of numerous public institutions – such as environmental authorities, federal and regional offices and ministries – and so is a kind of information broker for environmental information in Germany. 60 authorities and other federal or county institutions that provide environmental information are included in GEIN (http://www.geein2000.de)
The **Environmental Data Catalogue** (UDK – Umweltdatenkatalog) is an information system, which records environmental databases in public administration. The term "database" covers a wide area here. Projects, specialist tasks, programs are also described in the UDK. The system is supposed to give information on "who" has got "which" environmental data and "where" (http://www.umweltdatenkatalog.de)
The **Federal Landscape and Conservation Information System** (LANIS = Landschafts- und Naturschutz – Informationssystem der Bundesrepublik Deutschland) will regulate information on and access to databases, systems and other sources of information, communication with local and external systems as well as support management of data on objects, geographic data and multimedia documents. Included in this are fact databases with a GIS component, in which object data on protected areas, land utilization as well as protection of species and reasons for being endangered for evaluation of the status of nature and the landscape are combined with point, line and area data, coded geographically, saved, evaluated and made available.
The **Meta-information System for Cartography, Geodesy and Land Survey** (Metainformationssystem des Bundesamtes für Kartographie) delivers information on the available basic digital and analogue geographic data of the German land survey authorities. The geographic data can be researched spatially and thematically. They are described according to content, expanse, quality, area they refer to, and sale. Additionally, there are cartographic examples and links to land survey authorities (http://www.atkis.de)

Combining information of varying quality and standards in a GIS leads to results that are only seemingly "exact" or "clear". According to Volk and Steinhardt (1998) the following fundamental problems have to be mentioned:

- statistical evaluations must be based on spatial units of reference (e.g. landscape units, watersheds/catchments or administrative units),

- collecting or recording and maintain the data permanently is the most expensive (and often underestimated) part of a GIS,
- meta-information is needed for the files (e.g. accuracy, time reference, description or attributes, and
- systems become outdated very quickly as a result of the rate at which further development takes place.

A problem which is creating a lot of dissatisfaction is that of access authorization or copyrights of data, which has been compiled by state institutions. A general release should be granted for environmental data compiled by these institutions. High administrative expenditure and the costs for using data make it very difficult for many applications in Germany (at the moment) to make use of information, which is actually available in the public administration sector in decision-making processes.

6.2.3 Application of landscape information systems

Landscape is an extremely complex system (see Chapter 1.3). In order to examine such complex structures, GIS today provide effective tools. These tools allow complex combinations and connections between the different layers of information. For the first time it is possible to carry out analyses on a much broader spatial and thematic basis. Spatial and functional aspects are in the foreground of this development, which means that developing models and deriving information from existing basic data becoming more and more important. GIS are usually used for modeling interrelations in a landscape. On the one hand, this is the only way to guarantee the administration and processing of the extensive amounts of data acquired and on the other hand it is the only possible way to present the results visually (Dabbert et al. 1999). A good example of this is linking hydrologic models at the landscape level to GIS (see Chapter 6.4).

Using GIS is only worthwhile if important new findings can be made, information relevant to planning can be better processed and made more understandable and a better information flux between authorities, researchers, planners and other involved parties can be guaranteed. Haines-Young et al. (1993) describe the challenge: "As landscape ecologists, the question we need to ask about the landscape and the human impact upon it are complex and highly demanding of intellectual frameworks. The growth of the discipline has in recent years been stimulated by access to the new technologies for handling spatial information, which may help us to overcome some of the practical difficulties we face. However, investment in technology is only worthwhile if it allows us to solve outstanding scientific problems or to look at the world in new and more perceptive ways."

The current demands from landscape ecology on GIS are the analysis and modeling of the **relationships between cause and effect**. A GIS should support the following functions (Stow 1993):

- provide database structure for efficiently storing and managing ecosystems data over large regions,
- enable aggregation and disaggregation of data between regional, landscape and plot scales,
- assist in the location of study plots and/or ecologically sensitive areas,
- support spatial statistical analysis of ecological distributions,
- improve remote-sensing information-extraction capabilities, and
- provide input data/parameters for ecosystem modeling.

Landscape information systems in a wider sense are currently being set up for example in nature conservation for many purposes so for the Berchtesgaden National Park (Germany, 33,000 hectares) as part of a "Man and biosphere research project" and for other national parks, biosphere reserves and nature parks in Germany, Austria and Switzerland. Cross-border information systems are currently under construction for the adjacent national parks Sächsische Schweiz (Saxony, Germany), Labske piskovce (Czech Republic), and for the Pfälzerwald - Vosges du Nord (Germany, France) biosphere reserves (Werder 1998). Federsee Conservation Area in southern Germany, the clear requirements laid down for the system play an important role in making sure its use is targeted: documenting of plant and animal species in clearly defined plots, ascertaining what conservation measures are necessary and collecting clear information on complicated property situations (Wernicke 2000).

An increasing number of digital information systems are being set up at the **environmental authorities** and specialist local authority offices, too. A systematic overview over existing data, its quality and availability will be necessary to enable coordination of information required for particular tasks, access to existing data and data acquisition. Up to now a large part of the specialist data was or is only available in analogue form (reports, maps, aerial pictures etc.). Maps and plans are often not up to date, putting different maps together requires a lot of technological effort and is inflexible. Moreover, specialist local authority offices need access to a whole range of data that is distributed amongst separate authorities and institutions in addition to their own specialist planning. Landscape information systems could make a great contribution to fulfiling these tasks, especially if they are extended to become geographic "documentation and information systems" by adding a data catalogue. Such a system could be used to support management and planning of tasks and would offer many possibilities for spatial data analysis of clearly-defined areas as well as flexible and economic ways of presenting the results.

Meanwhile all the German federal states have environment and landscape information systems at their disposal. The landscape information system in North Rhine Westphalia (LINFOS NRW), for example, is a collection of numerous specialist files on conservation such as: internationally significant conservation areas, well-protected biotopes, landscape conservation areas, biotopes worth being protected, locations where plant and animal species on the red list of endangered species are found and records of vegetation. Hamburg City Council has developed a similar information system for the areas of forestry, green areas and conservation. One main focus there is the implementation of spatial instruments for information and analysis.

The following **advantages** and uses can be expected when **using a GIS** and the means of digital data storage and data query or analysis it offers (LÖBF 1998, Page et al. 1993):

- secure storage and improved relevance of specialist data in authority offices and avoidance of unnecessary expenditure when getting specialist data by having suitable interfaces and data transmission routes,
- faster access for specialists from their work stations or from outside to the various data at the specialist institute,
- creation of new methods of analysis or improvement of existing processes by using different specialist databases,
- effective presentation of evaluation and analysis results in a suitable form (thematic maps, tables, reports ...),
- saving time and effort, and
- securing and improvement of the quality of work.

GIS can be used for:

- landscape planning and environmental impact assessment (see Chapters 7.3 and 7.4),
- protection of biotopes and species (see Chapter 7.7),
- monitoring (see Chapter 4.2), and
- efficiency checks (determination of whether or not the goals of conservation projects have been achieved, ascertainment of whether it is to make any corrections and ways in which processes could be optimized).

On the basis of topographic and thematic data, which are available in landscape information systems, it is possible to analyze the **landscape structure**. The necessary tools for these purposes (models, software programs – e.g. FRAGSTATS) can be linked to a GIS. Here we can only introduce into this theme in an exemplary manner:

Landscape identity is forged by the combination and organization of separate landscape elements it contains (see Chapter 2.3). The structure of the landscape can be seen as an expression of the diversity of the site. Abiotic conditions determine the diversity of the surface cover in a natural landscape. Today's cultural landscape is a product of the relationship between man and nature. By comparing the way in which current uses of the land are structured (diversity determined by cultural landscape) with the diversity of natural conditions in a specific area (diversity determined by natural conditions) the structure of the landscape can be used as an indicator to characterize the influences of cultivation (Walz 2001).

For Saxony (Germany), the Shannon diversity was calculated as an example on the basis of spatial environmental units (Figure 6.2-2). The details on land utilization were taken from CORINE land cover data, an European program to survey land utilization on a scale of 1:100.000 (Table 6.2-1). Loess landscapes that are heavily used for agriculture such as the Central Saxon loess soil district had noticeably low results. Large areas of forest, in the Erzgebirge (Ore Mountains) for example, also proved to be not very diverse. In comparison, landscapes with diverse structures such as the Dahlen-Dübener heathland, the Königsbrück-Ruhländer heathland and the Upper Lusatian pond district were noted for their high results. However, some urban areas, such as the Dresden district along the river Elbe, also show high values.

It is possible to interpret the results at this level; however, it is very important to examine which classification of land utilization was used in the questions. It is therefore necessary to use further parameters when carrying out an evaluation of the results because, for example, diversity in areas with settlement should be interpreted differently to the diversity in landscapes in a near-natural state. It is recommendable to include information on how near to a natural state the area is and to what extent the area has been divided into smaller plots, as well as information on linear elements such as waterways.

Assessment of landscape structure can be used for planning and monitoring purposes, especially if it deals with large areas and long-term observations. Landscape structure is an important feature for reflecting changes in the quality of the environment over longer periods of time. Suitable data levels should therefore be integrated into GIS. Furthermore, landscape structure can help to identify areas important for nature conservation. In order to be able to assess the meaning of individual indices in landscape structure analysis, they must be combined with information on landscape functions (see Chapter 5.2)

It is possible to use landscape structure in habitat models to show the links between landscape and organisms. In this case the abiotic properties of the landscape can be linked to the demands of organisms in order to make forecasts about specific areas. Alongside models for meta-populations and the dynamic of island habitats, simulations of population spread of single species (see Chapter 2.8) are being increasingly used.

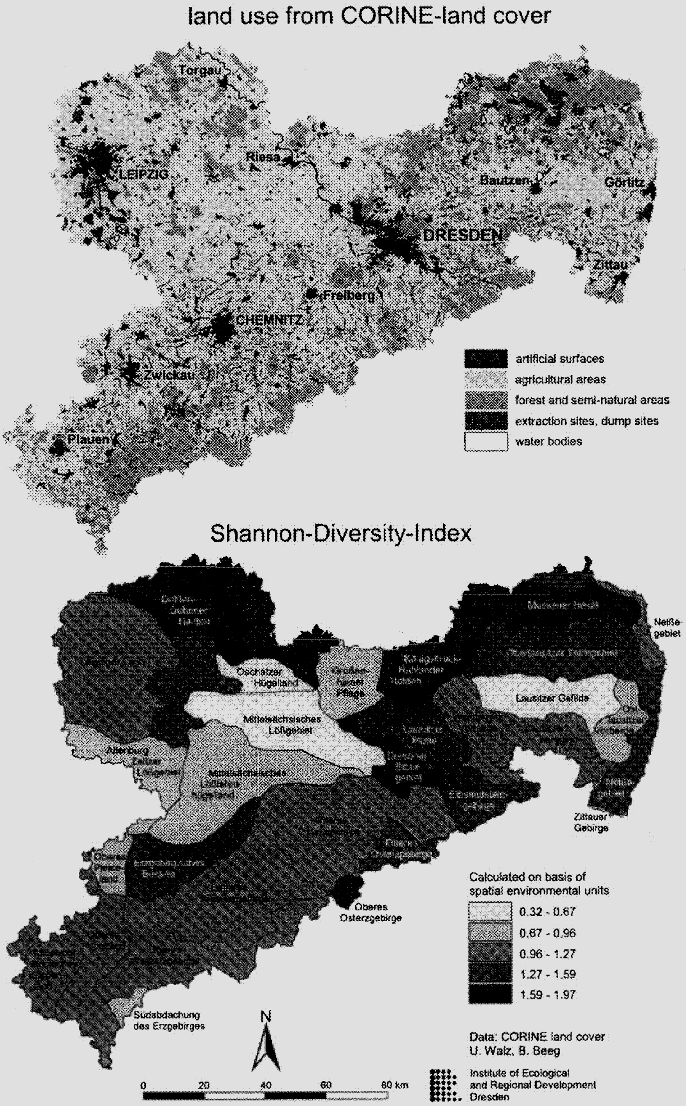


Figure 6.2-2: Landscape structure assessment (Saxony, Germany)(Data source: Stat. Bundesamt 1997)

6.2.4 Outlook

Meanwhile GIS became an important tool in spatial planning. Evaluation of planned uses of environmental resources, which are in competition with each other and increasing complexity of the connections between causes, and effects that should be taken into consideration are increasing, as is the amount of information available. Existing data must be used more analytically and should also be linked synoptically. Using GIS for the purposes of landscape ecology and environmental planning in future planning and monitoring duties is in the light of all this advantageous and definitely the right approach to take. Digital data and methods provide new possibilities for spatial analysis and creation of spatial models. Combining different thematic levels, creation of buffers, statistical functions or creation of surface models using data in the form of points show how capable such systems are in assessing data in spatial form in a way that would, if it were done analogously take up a great deal of time or may not even be possible at all.

In order to minimize the danger using GIS solely for presentation purposes, it is important to demonstrate that it is an analysis as well as a planning tool.

Despite all the advantages and opportunities presented, it should be kept in mind that the complexity of landscapes and ecosystems cannot be completely understood even with the best GIS. Currently only a fraction of ecosystematic interrelations can be investigated using a range of simplified assumptions. In this way, GIS could reach the level of ecological information systems or complex landscape management systems (Duttmann and Mosimann 1995). Combining new theoretical models and new methods such as the further development of GIS data models is one of the most important tasks of the next few years (Blaschke 1997).

6.3 Remote sensing and digital image processing

6.3.1 Development of remote sensing

Remote sensing means recording data about the surface of the earth from a certain distance without carrying out a direct inspection or drawing up maps. This became possible with the invention of photography. With the advent of aviation came the possibilities of taking pictures, first from balloons and then later from planes. Remote sensing from space was developed with the advent of space travel. Pictures were taken from planes using the traditional method of photography, whilst digital systems quickly won the upper hand in remote sensing using satellites.

Today, it is almost impossible to deal with topics in landscape ecology in its broadest sense without the use of data collected by remote sensing. Troll (1939), a German geographer recognized this fact stating "Familiarity with ecological connections in the landscape as a result of terrestrial investigations ... makes it possible ... to draw boundaries on maps from aerial pictures and aerial maps". Maximum use can be made of aerial pictures provided enough is known about the causal relationships between the different elements (climate, rock forms, water and soil erosion, and plant cover) and their typical structure within the area.

The advantages of being able to see extensive interrelations from above are obvious. Naveh and Lieberman (1994) concluded that: "The fields of remote sensing and information science have a significant role to play in holistic landscape evaluation. [...] High and low-resolution sensors provide specific applications for many ecological systems."

6.3.2 Information from remote sensing data

The information from remote sensing data for landscape ecology comes from different regions of the spectrum, depending on the backscattering properties of different surface materials such as soil, vegetation type or areas of water (Figure 6.3-1) and the sensor used. **Green vegetation**, due to the pigmentation of the leaves, generally absorbs a high level of red and blue parts of the visible spectrum, hence, vegetation looks green because of a lower level of absorption of the green spectral range. Leaf surfaces disperse a high degree of infrared light, which makes this wavelength very suitable for distinguishing between different vegetation types. A leaf that is dry or ill, and whose structure has been damaged, can be recognized by means of low reflection in near infrared part of the spectrum. There is also a high level of backscatter of short wave infrared as a result of the low water content.

The **spectral areas** mainly used are those of visible light, infrared and the thermal area. The human faculty of perception lies between 0.4 and 0.7µm and the remaining wavelengths can only be recorded and used by means of remote sensing devices. Digital recording of the radiation reflected by the earth's surface does not take place in a continuous spectrum but rather in separate spectral channels which have a width of about 0.1–0.2µm. Most satellite sensors record in near infrared (NIR = near infrared 0.7–0.9µm), a region that can also be recorded by color infrared (CIR) aerial pictures. Whilst visible light consists of near and short wave infrared radiation that has been reflected, thermal infrared (TIR) results from the characteristic temperature of an object. Optical sensors can only pick up radiation in spectral ranges that are emitted from the earth's surface where there is no absorption or dispersion of the radiation by ozone, oxygen, steam, carbon dioxide, methane or nitrogen oxides. Such an "atmospheric window" lies between 0.3 and 1 µm and there is a second window in the thermal infrared range. Clouds and haze cause non-selective dispersion of the radiation and so appear to be gray-white.

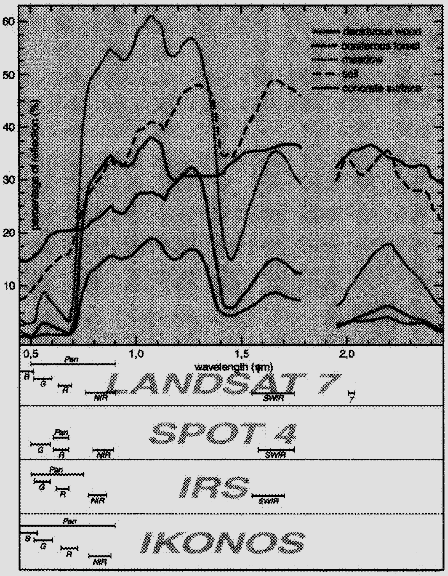


Figure 6.3-1: Reflection of selected land use categories and spectral bands of sensors

6.3.3 Remote sensing systems

According to the carrying platform and to the recording technique it is possible to distinguish between the following systems:

a) airplane systems
   - black to white aerial pictures (analogue),
   - CIR aerial pictures (analogue),
   - digital scanner data, and
b) satellite systems
   - photographic imagery (analogue),
   - digital scanner data.

Whilst most of the earth observation sensors are passive, i.e. they only receive solar radiation reflected by the earth's surface or heat radiation emitted. A satellite in polar orbit can record every point on the earth but it cannot do so at any given time. As a result, the chances of being able to record in a cloud-free situation in Central Europe are greatly reduced. **Clouds** pose a great problem when using remote sensing in the range of visible light to collect information about the earth. It is often difficult to record enough data for a particular area when there are no clouds, which makes it difficult when it comes to choosing satellite data. Only one to four recordings per year are usually free of clouds (Kühbauch et al. 1990).

However, **radar sensors** (Table 6.3-1) are active sensors. They carry a source of radiation, which is ideal as it is constant, has a defined wavelength and radiates active radar waves.

Table 6.3-1: Operational radar satellites (after Schneider-Sliwa et al. 1999)

satellite	operating since	spatial resolution (in m)	width (in km)
ERS-1/2 SAR	1991/1995	25	100
JERS - 1	1992	18	75
Radarsat	1995	10 – 100	50 -500
Envisat	1999	30 –1000	56 - 400

The ground resolution of operational radar satellites lies between 18 and 30 m, which makes them interesting for questions in landscape ecology. However, the radar sensors only deliver information about the three-dimensional structure of the surface, not about the reflectance of materials. The data can only interpreted by the help of mathematical processes and gives less impressive images than **optical sensors** (Table 6.3-2).

One of the advantages of using **airplanes** as a platform lies in the fact that it is possible to react quickly and flexibly to different weather situations. In spite of the new high-resolution satellite sensors, the resolution of airborne remote sensing data is not yet reached. Indeed high resolution images, both aerial and satellite, needs to include a digital elevation model for geometric correction.

The main advantage of **satellite sensors** compared to airborne is that large areas can be covered, which makes the time-consuming task of processing each individual aerial picture and putting them together bit by bit unnecessary. Furthermore, there is no need to organize individual flights, which are also expensive.

Continuous recording of data by remote sensing from space started with Landsat–NASA satellites. Landsats 1–3 had a resolution of 60m. The latest Landsat 7 manages a resolution of 15m, using the newly added panchromatic channel. The three channels of the SPOT Satellites record radiation in visible and near infrared range with a spatial resolution of 20 by 20m. An additional panchromatic operational mode has a resolution of 10 by 10m.

Since 1995 the panchromatic sensor of the Indian satellite IRS-1C delivers a resolution of 5.8m, which is a completely new quality compared to all of the previous systems. It was mainly designed to be used for inventories and planning for the Indian State.

Table 6.3-2: Important optical remote sensing systems (B-blue, G-green, R-red, NIR-near infrared, SWIR-short wave infrared, TIR-thermal infrared, Pan-panchromatic)

satellite	operat-ing since	recording system	spectral bands (μm)	spatial resolution (m)	swath-width (km)	alti-tude (km)	revisit rate (days)
Landsat 1-3	1972	MSS, RBV	0.5-06. 0.6-0.7 0.7-0.8 0.8-1.1 10.4-12.6	79 x 79	185x 170	930	18
Landsat 4-5	1982, 1984	MSS, TM	0.45-0.52 (B) 0.52-0.60 (G) 0.63-0.69 (R) 0.76-0.90 (NIR) 1.55-1.75 (SWIR) 2.08-2.35 10.4-12.5 (TIR)	30 x 30 120 x 120	185 x 175	705	16
Landsat 7	1999	TM, ETM	0.5-0.9 (Pan) 0.45-0.52 (B) 0.52-0.60 (G) 0.63-0.69 (R) 0.76-0.90 (NIR) 1.55-1.75 (SWIR) 2.08-2.35 10.4-12.5 (TIR)	15 x 15 30 x 30 60 x 60	183 x 170	705	16
SPOT 1, 2 und 3	1986, 1990, 1993	HRV	0.50-0.73 (Pan) 0.50-0.59 0.61-0.68 0.79-0.89 1.58-1.75	10 x 10 20 x 20	60 x 60	830	26
SPOT 4	1998	HRV	0.61-0.68 (Pan) 0.50-0.59 0.61-0.68 0.79-0.89 1.58-1.75 (SWIR)	10 x 10 20 x 20	60 x 60	822	26
IRS 1C IRS 1D	1995 1997	PAN LISS-III	0.50-0.75 (Pan) 0.52-0.59 (G) 0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (SWIR)	5.8 x .,8 23 x 23 70 x 70	70 x 70 142 x 142	817	24
IKONOS	1999	PAN	0.45-0.90 (Pan) 0.45-0.53 (B) 0.52-0.61 (G) 0.64-0.72 (R) 0.77-0.88 (NIR)	1 x 1 4 x 4	11 x 11	680	1-3
EROS A	2000	PAN	0.50-0.9 (Pan)	1.8 x 1.8	12.5 x 12.5	480	1-4

IKONOS (Figure 6.3-2) has been delivering panchromatic data with a resolution of 1m since 1999. It can be assumed that more systems with this degree of resolution will be available in the near future and that they will open new areas in environmental planning and landscape ecology. However, the price level of the data delivered by these systems is very high and the advantage of being able to cover extensive areas with satellite data is lost because of the small swath width.

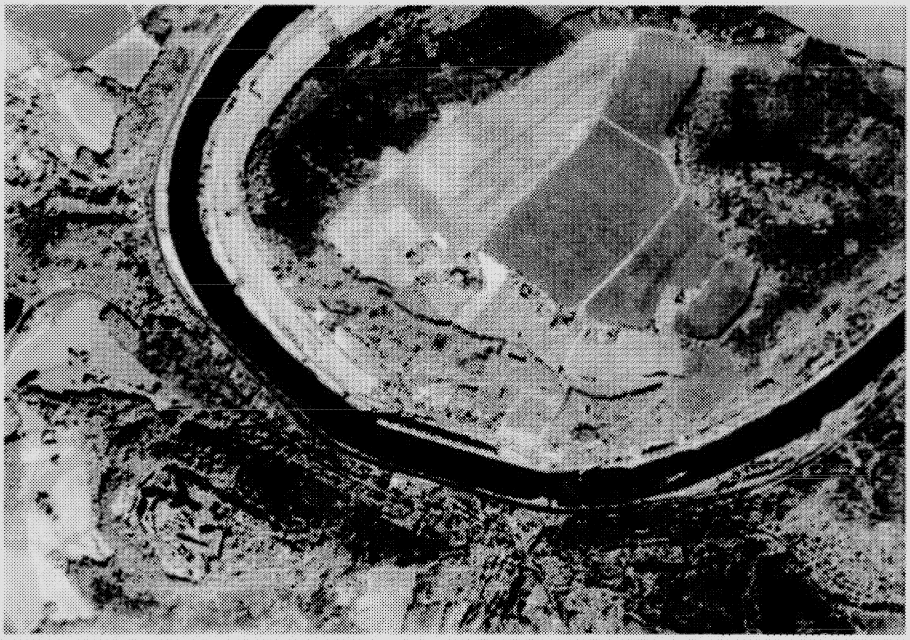


Figure 6.3-2: Panchromatic IKONOS-Image (Saxony Switzerland© Space Imaging Europe SA)

6.3.4 Application of remote sensing data for landscape ecology

Satellite images are primarily suited for purely visual interpretation. Combined with overlaying geographic information they form an excellent basis for the illustration of spatial facts. Multi-spectral classification of satellite data for drawing up maps of surface cover is a (semi-)automated evaluation method. Further information that can be gained is interesting as far as ecology is concerned (for example):

- information on the structure and texture (of landscapes or landscape elements),
- thermal information (on surfaces),
- biomass, e.g. vegetation index or leaf index,
- dynamics, changes in land use, and

- information on altitude.

Remote sensing can be applied within very different task areas of landscape ecology and planning, e.g.:

- urban ecology (identification of urban or landscape structure),
- biotope mapping,
- land use and landscape planning,
- agricultural statistics,
- analysis of current land use patterns,
- cartographic processing of planning,
- observation of the effects and, to a limited extent forecasting, of natural risks (e.g. desertification, flooding, landslides, rock falls, wind damage, fire, water pollution), and
- observation of forest damages (by air pollution, insect outbreaks, climatic stress wind, snow, dryness).

Probably the most important area in which data from remote sensing can be used is that of regional and global monitoring of changes in land use, vegetation cover and environmental media (see Chapter 4.2). Earth observation systems are most suited for delivering information for such monitoring purposes as they cover extensive areas. They record regularly and guarantee comparable information over long periods of time (e.g. from Landsat). It is absolutely necessary to consider and investigate the processes which take place in the different dimensions of space and time from a landscape ecological or holistic approach.

In principle, remote sensing data should generally be considered as only one source of data within a GIS (see Chapter 6.2).

Satellite data must be **preprocessed** before they can be used for different applications. Errors in the data caused by geometric distortion as it was recorded or where atmospheric factors had an effect should be corrected. Furthermore, sensor errors should be taken into consideration and corrected where necessary.

Satellite information must be entered into a standardized system of coordinates so that it can be combined with other spatial information. Reference points that are clearly recognizable and whose coordinates are known are marked on the satellite image. The data is then converted into a geodetic system of coordinates by means of polynomial transformation.

The cultural landscape is changing very quickly and so there is a lack of up-to-date information on land use. Topographical maps often do not contain the information required, are frequently out of date, and do not distinguish clearly enough between particular land use forms. It is possible, by combining high-resolution panchromatic images with multi-spectral data of a lower spatial resolution, to achieve a high geometric resolution without losing thematic information.

By using such a composition and with the use of panchromatic data, changes in land use can be quickly recognized visually. Very good general maps can also be drawn up by superimposing other geographic data. Superimposition of administrative boundaries, roads, railways, watercourses (Hildebrandt 1996) could be considered when dealing with tasks, for example, in forestry, environmental planning, geography and cartography. The person observing such illustrations can get additional information of about the surrounding landscape (Figure 6.3-3).

Figure 6.3-3: Satellite map. Overlay of vector data and IKONOS image data (Data source: Space Image Europe, Office for Environment and Geology of Saxony)

Potential areas of satellite image products' application in landscape and urban planning are:

- updating of land use maps,
- mapping of town structure types,
- determination of the extent of surface sealing,
- overall view of potential of land use conflicts,
- drawing up of general maps for terrain mapping,
- visual recording of very structured areas to determine for which areas further on-site mapping is necessary, and

– updating of existing geographical data such as mapping of biotypes.

It is possible to create three-dimensional representations of the landscape by including **digital elevation data**, e.g. from laser scanner recordings carried out from airplanes. Such perspective landscape presentations allow a better understanding of geographic areas and so make deeper analysis of landscape ecological conditions and interrelations possible. In addition, further levels of information such as planning concepts (buildings, settlements, traffic systems, artificial lakes etc.) or the results of simulations can be inserted into a picture of the real landscape. Their effects on the landscape can then be assessed from the varied viewpoints.

6.3.5 Digital spectral land use classification

To detect and classify separate areas of land use, the different reflective properties they have are recorded in different channels of the satellite scanner (Figure 6.3-2). There are two basic methods of classification: supervised and unsupervised. In an **unsupervised classification process**, the division of classes is carried out automatically by a classification algorithm. The classes that result from unsupervised classification must then be interpreted and assigned to particular land uses.

At the start of **supervised classification** assignment of areas on which information exists either from inspections or existing geographic information is interactively determined on-screen. A decision function is derived from these "sample groups". All the pixels in the whole image are then compared to the characteristics of the sample groups and are assigned to an object group by the decision function (Wieneke 1988).

Spectral separation of the individual classes and spatial resolution are limitations in classification. The problem of separating classes according to the spectrum becomes clear, for example, in land use classes such as grassland and germinating crops. Therefore, it is important to choose the time of recording correctly or to use several recordings from a given year to distinguish between fields that have not yet been ploughed and grassland.

It is also important to note that only the type of surface cover can be recorded and there is no information regarding function. A sealed area can, for example, be recognized as such with a degree of certainty. However, it is not as easy to determine whether it is a road or a parking lot.

The resolution of multi-spectral scanner systems, which is usually between 4 and 30m, limits the ability to record small objects. An object that is smaller than the given dimensions or is only partially contained in a pixel will be received as a mixed signal including information from the environment surrounding the object and it will not be possible to identify it clearly.

Hyperspectral classification is used to identify individual minerals or water components by their typical behavior when absorbing or reflecting the spectrum. It is also used to distinguish between several surface materials in urban regions (roofs). To do this, it is necessary to record the characteristic absorption bands with sufficient spectral resolution. Such spectrometers or hyperspectral sensors in airplanes are currently used successfully, mainly in dry areas where is no plant cover, for geological exploration. It is conceivable that this equipment could be used for mapping biotopes, investigating water quality or forecasting harvests. Such systems are still at the development stage.

Methods of multi-spectral classification look at each pixel separately. However, methods of **texture analysis** evaluate the gray scale values of the neighboring pixel and their relationships by using texture filters. Texture is defined by means of elements in a given form and size, and by the recurrence of this pattern. This approach is only of limited use for the characterization of natural structures, as they neither usually contain simple, clearly defined elements nor occur in a rigid recurring pattern (Turner and Gardner 1991b). Structures that are determined by utilization have recognizable regular recurring patterns. Examples of this are the rows in corn cultivation or in intensive cultivation of fruit, or the regular structure of individual elements such as division of fields into typical sizes. In some cases it is possible to improve multi-spectral classification by including such textural parameters (Kaifel and Straub 1990). For this aim, one can distinguish between characteristics of texture such as homogeneity, non-homogeneity, contrast, mean value, aberration from the standard and entropy. Characteristics of texture and multi-spectral properties are connected by means of the classification polynomial, which includes a channel containing the characteristics of texture.

New approaches in digital image processing are based on **segmentation of images** into homogenous areas on different hierarchical levels (Blaschke 2001). Distribution of gray scale values (texture) and the form of individual units of utilization play an important role here. Areas that have been divided into segments can then be integrated into the classification process or used directly for defining boundaries for objects.

Methods of digital image processing can also be used for the **extraction of linear landscape structures** (Figure 6.3-4). Linear elements found in satellite images are linear infrastructures such as roads, paths, railway lines or power lines. Every boundary between two areas of different utilization is to be regarded as a linear element. In ecology such areas are called ecotones. The margins of every land use plot are dominated by species that are only found or are mainly found near the boundary. Therefore, an ecotone is a transition zone between neighboring ecological systems that has its own characteristics (Hansen and Di Castri 1992, see Chapter 2.5).

Linear infrastructures often cause disruption, ecotones however are as a rule regarded as positive. Whilst existing geographic data can be used in the evaluation of infrastructures, these data sources contain very little information on ecotones. In particular, boundaries between grassland or arable land and the edges of fields bordering other fields or roads can not be distinguished. Modern remote sensing methods are necessary as they can fill the gap in information. Johnston et al. (1992) see great potential in determination of ecotones from panchromatic satellite images: "Satellite imagery is useful for boundary detection at landscape to global scales, and it provides an objective means of identifying and quantifying ecotones which can be applied to large areas." Smaller landscape elements (e.g. undergrowth) can also be picked out in high-resolution satellite data but the automatic cut-off detection processes that are based on the evaluation of differences in gray scale values between neighboring pixels are not able to distinguish whether such an area is the boundary between fields and forest or between a tarred forecourt and the roof of a house. The cut-off areas that are detected should, therefore, either be combined sensibly with existing data or should be masked. Another possible approach is the evaluation of classified data or existing data, which has been used for another purpose, for example, biomass calculated using NDVI data. Johnston and Bonde (1989) use NDVI values from Landsat TM data for the determination of ecotones.

Landsat TM recordings with channel 6 contain **thermal information**. The gray scale value of these heat images is closely connected to the surface temperature of the object displayed. Conclusions on the absolute surface temperature cannot be made without calibration using the help of terrestrial measurements. In comparison, it is possible to make reliable statements on the relative differences of the surface temperatures of different objects on the surface of the earth (Hildebrandt 1996). Thermal information becomes important when the connection is made between energy balance and the landscape. Ripl (1995) assumes that the structure of the earth's surface will be more long-lasting the more efficient an area is at dissipating the energy impulse from the sun's radiation. Dissipation of energy is achieved by a combination of local evaporation, dissolving and biological production processes. In terms of evaluation this means that areas with a high level of reflection have a low level of landscape efficiency and those with a low level of reflection a high level of landscape efficiency.

Figure 6.3-5: Extraction of linear features from IRS-1C panchromatic data (Data source: ANTRIX, SIE, Euromap Neustrelitz)

The different characteristic levels of reflection of living green vegetation in particular spectral ranges mean that **spectral indices** can be developed, which make it possible to distinguish between areas with living vegetation cover and areas where there is no vegetation or the vegetation has died. As living plant populations reflect more in the near infrared range than inanimate surfaces and less in visible infrared range it is possible to form a vegetation index using these two spectral ranges. The **Normalized Difference Vegetation Index** (NDVI) has proved to be the index most used: As Netzband (1998) was able to show the values of the vegetation index correlate with the extent to which the land is sealed in urban areas.

The Green Component (Hildebrandt 1996) offers a further possibility for biomass evaluation. It is calculated using the so-called **Tasseled Cap**. Further Tasseled Cap coefficients are brightness components, areas that are indicated with low vegetation and high level of reflection and moisture components that indicate water or humidity.

6.3.6 Summary and outlook

Remote sensing data are an important basis for dealing with questions in landscape ecology. It makes it possible to get current information on large areas of land. Used alongside visual evaluation and superimposing other geographical data it is possible to classify land use areas as well as carry out a whole range of other thematic evaluations. Technical development shows a trend that is going into two directions. Firstly, the resolution of satellite data is improving with every mission; it is expected that in the near future a spatial resolution of 0.5m will be possible. This will mean that satellite remote sensing will have achieved the same resolution as aerial photography. Secondly, surveys carried out using airplanes are becoming more important, for example, when gathering highly accurate data on terrain by means of laser scanning. Moreover, use of radar sensors will undoubtedly play a more important role in the future as it is the only method which can make recordings regardless of the weather situation possible.

It can also be ascertained that the new generation of satellites (e.g. IRS-1C, IKONOS) will not really be able to make a significant improvement in the classification of land use areas. Landsat TM data is still the most suitable for classification with its seven spectral channels, one of which of course is low resolution. New digital image processing technologies are under development. In future the combination of spectral and textural characteristics will be important for an object-oriented classification, instead of single pixel based classification algorithms.

For the purpose of application-oriented visualization, remote sensing provides a method that can be processed and used with a relatively low amount of effort. If data is externally processed in advance, it is possible to include remote sensing data in an analogue work process or on a PC, which is not equipped with a GIS. Provision of current information on land use covering whole areas is important for planning authorities and offices in particular.

Integration of high-resolution satellite remote sensing data into the basic data and information systems of the survey offices and individual specialist institutions will be decisive for its future use. It can be hoped and expected that the availability of graphic geographic information on actual surface cover can make a contribution in supplementing the sometimes abstract information that is found in planning documents and maps to achieve a better understanding of the consequences in intervention in the decision making process.

6.4 Models in landscape ecology

6.4.1 Introduction

Society needs a way to handle a landscape as a whole, so that the human manipulative capabilities do not have too much headstart over our knowledge about the impacts of these manipulations (Odum 1969). However, extent and rate of effectuate changes in landscapes still exceeds, to a high degree, the scientific capability to reliably predict long-term impacts of technological developments on natural cycles and processes. Human impact on landscape pattern, material fluxes, habitats for plants and animals, but also on socio-economic situations has in fact reached a degree that may lead to irreversible changes and put at risk the natural systems essential for life support. Thus, landscape ecology and other environmental sciences have to develop suitable and improved methods to assess the impacts of anthropogenic changes in landscapes and to develop a conceptual base for sustainable land use.

During the last few decades it has turned out that models are suitable instruments to improve understanding of natural or economic systems. Additionally, they seem to enable comparison and assessment of results from factors that are assumed to influence these systems. By formalization and generalization of the complex reality, landscape models – like any other kind of model – provide the opportunity to connect detailed knowledge of different disciplines (Leser 1991a). Thus, it becomes possible to assess the related ecological and economic consequences of alternative management strategies or potential impacts of human induced landscape changes. In spite of the recent progress, the evaluation of integrated dynamic landscape models is only at the beginning of a far-reaching development. This shortcoming stands to reason considering the lack of quantified data on some topics, the high complexity of the task, as well as the methodological problems to get data in landscape ecosystems. Wenkel (1999) describes the five steps of development from single models to complete model-GIS-integration, which is characterized by coupling and interactive information exchange between sectoral dynamic process models among each other and with a GIS (see Chapter 6.2), as well as interactive handling. This chapter deals with the development and application of models for the investigation of several parts of the landscape ecosystem including the state of the art on integrated dynamic landscape models. This includes both technical and theoretical aspects.

6.4.2 Landscape ecology: Models for the investigation of complex topics

A **model** is a simplifying simulation of complex shapes from the reality and not the reality itself. Complexity is, thereby, a feature that results from the modeler's perception of the system in question (Schultz 1997, Wenkel 1999). The view of the modeler and thus the spatio-temporal resolution of the treated system are, of course, influenced by the modeling objective.

In the past, several attempts have been made in order to approach methodologically this complex topic within its theoretical framework (Finke 1994). However, this goal has yet to be reached. This insufficiency is caused on the one hand by a specialization of bio- and geo-sciences. On the other hand, a lack of suitable methods to combine the perceptions of different ecological disciplines, socio-economy and computer sciences was and mostly still is the reason for insufficient entire landscape synthesis or modeling. Thus, a **huge amount of models** have been developed within the single subject areas of landscape research. These have mostly synthesized the existing sectoral process knowledge (Wenkel 1999). Using the example of models to investigate water balance and waterbound material fluxes, we will highlight some general tendencies, problems and potentials of their application.

6.4.3 Modeling the water balance

The first models for the calculation of the landscape water balance stem from the late 1940s. Since that time, and due to the manifold requirements of the investigation of the water balance, the development of these models has undergone rapid progress in various manners (Dyck 1983, Xu et al. 1996). In general, one can differentiate between three **methodological approaches** to the modeling of the landscape water balance today:

- **physical-deterministic models** that are based on the fundamental laws of physics (mainly hydro- and thermodynamics), chemistry, biology, etc.,
- **conceptual models** that consider these laws in a simplified way and work simultaneously with empiric approaches, and
- **empiric-statistical models** that are only based on empiric measured cause-effect-relations of system in- and outputs, without the demand to comprehend the basic legalities.

The transitions between these approaches are fluid. Furthermore, hydrological processes always show deterministic as well as stochastic features. Both are based on the inevitable simplification of the complex reality and the appearing defects and uncertainties that occur with the gathering of the input data (Nemec 1993).

According to the model type and purpose of modeling, it is possible to handle different **spatio-temporal resolutions**. In doing so, compromises have to be made mostly between targeted accuracy and the available data. In the case of investigating non-linear processes (e.g. precipitation - runoff), it has to be worked in hourly or daily steps, whereas for seasonal or year-specific qualities monthly or annual steps are sufficient. The potential degree of spatial resolution reaches from greatly aggregated approaches, in which the investigated watershed is subdivided in only few sub-basins with similar geophysical characteristics (lumped models), up to models that consider the variability of spatial structure (distributed models).

The possibility to work with data with a high spatial resolution is improved due to increased computer capacities, development of geographic information systems (GIS, see Chapter 6.2), and the increasing availability of digital data. In general, all input data used for model applications have to be prepared and modified depending on the specific calculation characteristics of the models (Petry et al. 2000, Volk and Steinhardt 1998). This is also important for deriving indicators for environmental conflicts, land use, water balance and morphological interactions in catchment areas. One main problem of large-scale investigations is verifying the results. As measured data are mostly unavailable, the investigation has to be hierarchically linked to studies on smaller scales (sampling and analysis at representative locations, mapping, measuring, and application of small-scale models) (Steinhardt and Volk 2000). Nevertheless, the application of these traditional methods is essential not only for verifying the modeling results, but also for improving basic knowledge about how the landscape ecosystem functions (Hauhs et al. 2000).

Society affects the fluxes of water, matter and energy within a landscape by the parameter land use. Models are used to describe the impact of land use changes on the **potential groundwater recharge** (Volk and Bannholzer 1999). For the most part, variants or **scenarios** (see Chapter 4.3) are investigated which base on assumptions on climate change or impacts of political decisions (Table 6.4-1, Figure 6.4-1, Volk et al. 2001).

Quite obvious land use changes result in appreciable shifts of the simulated total run-off, if related to the whole study area. The listed results (Table 6.4-1) do not allow derivations about local changes or conditions; which can be much higher than the averaged values. In this connection, an algorithm has to be considered which takes into account the predicted land use changes upon the area. The assumptions about the spatial distribution of land use changes can be made on the basis of considerations of plausibility, or additional models might be used (Fohrer et al. 1999).

Table 6.4-1: Examples of scenarios of land use changes and landscape water balance

region	orientation of the scenarios	land use changes	run-off change	authors
Northeast Germany	EU-agricultural reform	afforestation (4% of farmland)	-1%	Werner et al. (1997)
Northeast Germany	EU-agricultural reform	afforestation (32% of farmland)	-10%	Werner et al. (1997)
Hesse	agricultural policy: pasture premium	decrease of forest (42% to 13%) increase of farmland (44% to 73%)	+8%	Fohrer et al. (1999)
Hesse	agricultural policy: loss of animal keeping	increase of forest (42% to 49%) decrease of farmland (44% to 37%)	+2%	Fohrer et al. (1999)
Saxony-Anhalt	analysis of land use conflicts in priority areas (agriculture vs. groundwater protection)	afforestration of farmland	-9% to -2%	Volk and Bannholzer (1999)
Saxony	regional political decisions for the conservation of natural resources	consequences of different development scenarios (changes of protected areas, mining activities, sealed areas, cultivation practice, afforestation)	-2,3% (in average)	Volk et al. (2001)

Figure 6.4-1: Due to land abandonment and afforestation of mostly poor sandy soils in North-Eastern Germany, water balance and alterations are expected: Terminal morain landscape at the Parstein lake near Eberswalde (Brandenburg, Germany) (Photo: O. Bastian 1990)

6.4.4 Modeling waterbound material fluxes and water quality

The **outwash and transport of material, nutrients and pesticides** is mostly linked to an amount of water flowing out of a region. This results in an input of this material into the groundwater and surface water with an impact on the water quality. The investigation of these processes is often concentrated on phosphate (particle-bound transport through erosion: horizontal processes) and nitrate (soluble transport through seepage: vertical processes).

Examples of such **nutrient transport models** are shown in Figures 6.4-2 and 6.4-3. Most of the nutrient load of surface waters originates from **non-point sources**. To analyze these processes, the application of distributed parameter models in combination with GIS seems to be a useful method. According to the relation of the material fluxes in landscapes to hydrological processes (see above), most of the models investigating waterbound lateral and vertical material fluxes consist of a hydrological model combined with a material transport component. Several of these models are listed and described by Bork and Schröder (1996) and Grunwald (1997). One of the latest innovative models based on physically approaches is EROSION 2D/3D – developed in the 1990s in Germany (Figure 6.4-4). Several studies are dealing with the application of models to investigate the impact of political decisions and related land use changes on waterbound-material fluxes and water quality (Franko et al. 2001).

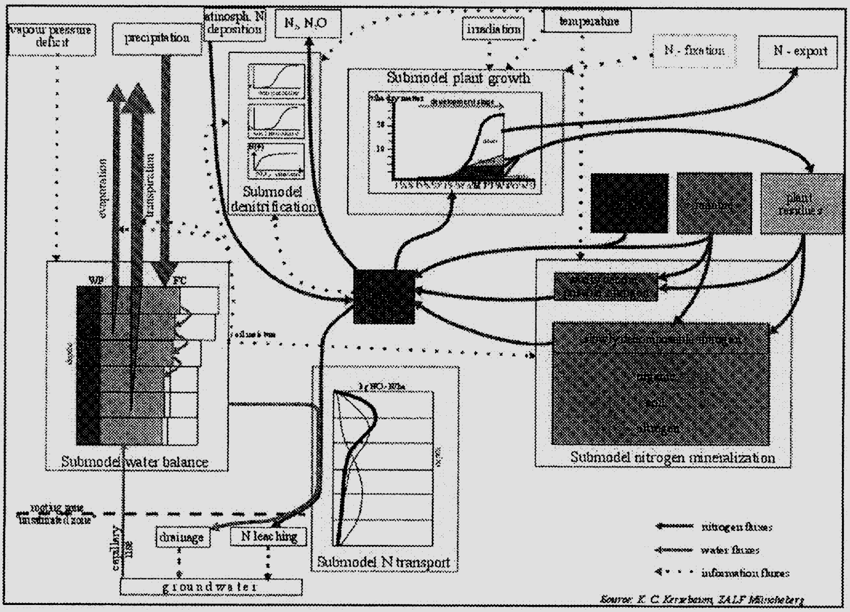


Figure 6.4-2: Modeling the nutrient balance: HERMES (Kersebaum 1995)

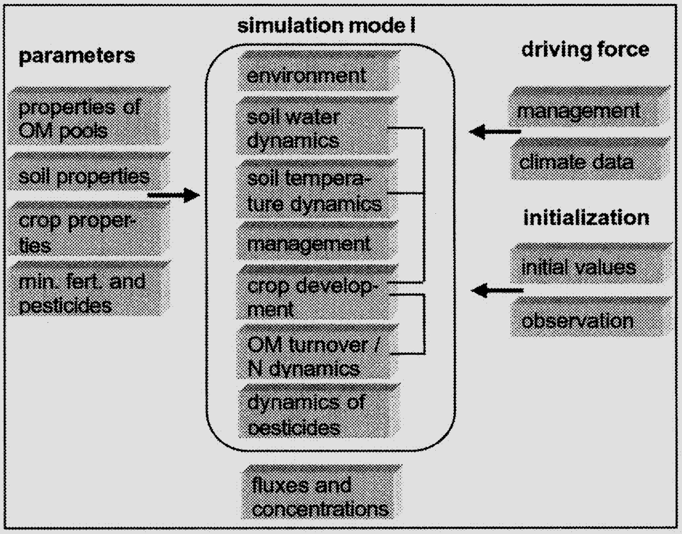


Figure 6.4-3: Modeling the carbon and nitrogen dynamics: CANDY (Franko 1997, Franko et al. 2001). The simulation system CANDY (CArbon and Nitrogen DYnamics) has been developed in order to describe the dynamics of the carbon and nitrogen turnover in the soil, as well as the dynamics of soil temperature and soil water content. All processes in the unsaturated zone are described for a one-dimensional soil profile. The system consists of both a simulation model which is imbedded into a user interface, and an environmental data base providing information about driving forces, initial values and series of measurements

6.4.5 Research sectors, models and scales

At present, many of the physically based approaches with a high spatio-temporal resolution cannot be effectively applied to medium-sized watersheds (Fohrer and Döll 1999, Grayson et al. 1992) because of the huge amount of input parameters required. Despite the much greater effort needed to parametrize, validate and run physically based models, simulated results often provide only slightly better or sometimes even worse correspondence with measured values than lumped-parameter models (Seyfried and Wilcox 1995). In this context, it should be mentioned that most of the common empirical models employed by environmental and planning offices and authorities rarely use more than three parameters (Hauhs et al. 2000).

Bearing these problems in mind, several models have been tested for their **scale-specific applicability** with respect to the time schedule and topics of research projects (Krysanova et al. 1996). Before applying a model, the algorithms used have to be checked. For example, most of the models that have an erosion component are based on different versions of the **USLE**

(Bork and Schröder 1996, see Chapter 5.2.2). It seems important to be able to adapt the model algorithms to the specific conditions of a study area. As most of the models were developed within research projects carried out in specific study areas, the possibility of transferring these methods to other regions needs to be tested.

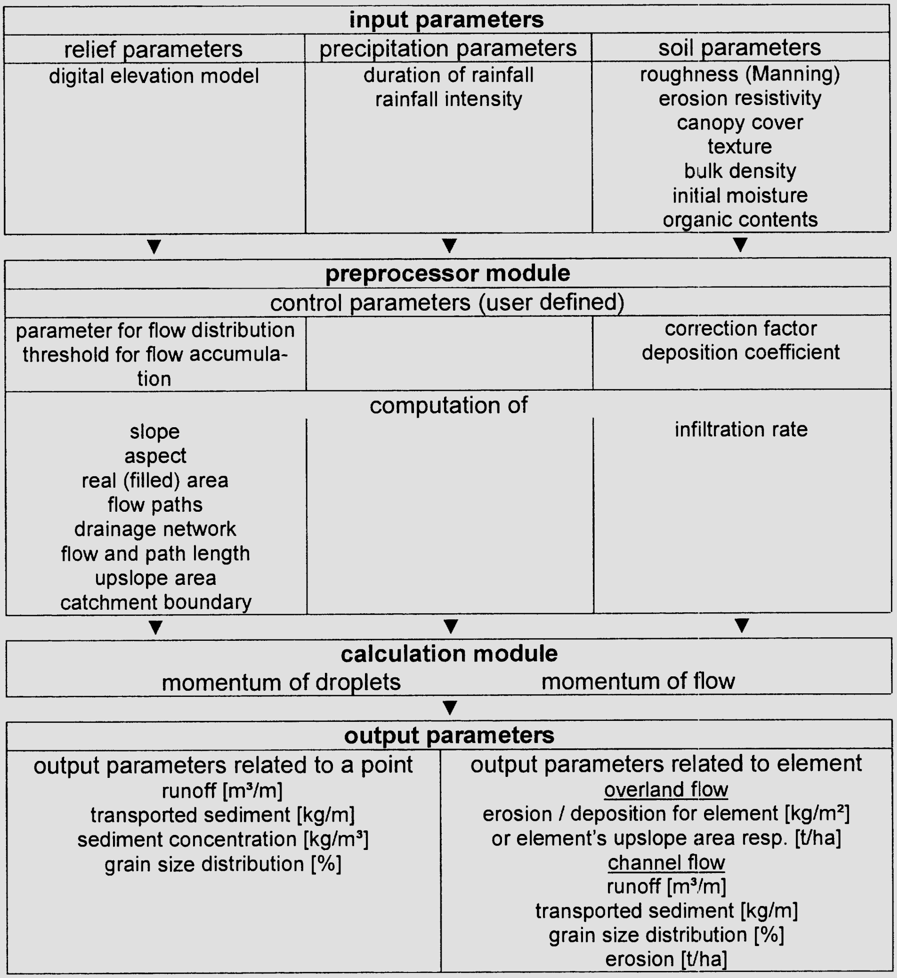


Figure 6.4-4: EROSION 2D/3D (Schmidt 1994, von Werner et al. 1999). E2D is a physically based soil erosion model for single slopes. The model calculates the amount of eroded material, the runoff volume, as well as the material deposition along a slope profile at single precipitation events. The model consists of three parts: the digital slope model, the erosion model, and the infiltration model. E3D is mainly based on the same algorithms like E2D. Additionally, the description of the spatial distribution of erosion processes is enabled by including a digital terrain model into the calculations

During the last years it has become clear that the solution of complex problems requiring knowledge from different scientific disciplines cannot always follow a single model application. Integrated modeling requires the usage of a common database, spatial and temporal scales have to be compatible "and a smooth exchange of data and results between the sub-models must be guaranteed" (Weber et al. 2001). For these purposes, oftentimes two, three or more stand-alone models in the fields, e.g. of (agricultural) economics, ecology and hydrology are developed or adapted joining in an **integrated model system** (Horsch et al. 2001, Weber et al. 2001). This requires the close cooperation of the research groups of the different scientific disciplines. The models are mostly integrated using GIS, and as "integrated model system" they are thought as instruments or tools with which political decision-makers will be able to evaluate land use variants or alternatives. However, as mentioned above, Wenkel (1999) differs between the following five development steps from single models to integrated dynamic landscape models:

Step 1: development of sectoral ecosystem models and application of GIS for landscape analysis,

Step 2: coupling of a GIS with statistical assessment models (model-based assessment of the landscape potential),

Step 3: coupling of a GIS with sectoral dynamic process models (spatio-temporal assessment of selected landscape functions, see Chapter 5.2),

Step 4: partial model-GIS-integration (data bank-based automatic coupling and mutual information exchange of GIS with sectoral dynamic process models), and

Step 5: complete model-GIS-integration (coupling and mutual information exchange between sectoral dynamic process models among each other and with a GIS, as well as with interactive operating).

Analyzing recent development, it has to be pointed out that most of the models can be assigned to the steps 1 to 4. In spite of various approaches to this direction one will find only few examples following the idea of dynamic landscape models (step 5). The main reasons for this lack may be the manifoldness and complexity of the methodological and research organizational problems to master. However, most of the modeling is still sector-oriented but uses increasingly the potential for coupling dynamic process models with GIS in the sense of landscape models (step 5).

6.4.6 Landscape models

The view taken in landscape modeling is that a landscape is understood as a spatio-temporal structure. The research object determines which components of the entire complex "landscape" have to be included in the scientific consideration and description. It is, thereby, not possible to include the description of the overall complexity of a real existing landscape. Hence, a landscape is described mostly on a meso-scale level, which enables a higher area-acridity in comparison to the global level, but not reaching the high spatio-temporal resolution of the local level (micro-scale).

First prototypes of dynamic and transferable landscape models were developed at the beginning of the early 1990s at the University of Maryland (USA). They integrate biological and physical processes and consider essential processes and their interactions with landscape structures (Maxwell and Costanza 1994). Beside this they enabled a distributed respectively spatial explicit simulation of process behavior in landscapes.

Nowadays work with **mesoscale level** models has become more and more important. They have to fulfil primarily a strategic task and serve as an assessment of the efficiency of alternative measures (Horsch et al. 2001). As these models should enable political decision making, they are considering cost-benefit aspects and thus include both **ecological and economic components**.

Because of their intermediary reference level, the conception of landscape models often requires a tightrope walk. On the one hand, the complexity of the man-environment-system has to be considered in the sense of the holistic approaches of global models. On the other hand the model structure is determined by the necessity of reduction to a few relevant factors in order to illustrate cause and effect correlation with the aid of technical-functional partial models. This results in a **simplification of the reality**, but also in a **systematization of complex correlation and interactions**.

With the simultaneous consideration of ecological and economic factors a resolution of the problem of coupling the different spatio-temporal scales of the different scientific disciplines can be found. This is especially true in consideration of the fact that the factor "space" is rarely of interest for economic models. Additionally, ecological and economic models consider the factor "time" to a very different degree. Therefore often a comparative-static approach is used that compares two static mapped conditions with each other. An **interdisciplinary modeling** requires the coordination between the time horizons of each research disciplines.

We now present **two examples of landscape models**. Formation and structure of the landscape model, as well as the couplings between the modules of the model are depending on the objective of the research project. Table 6.4-2 shows an example for modules of the landscape model "Kraichgau" by Dabbert et al. (1999) that has been developed for the analysis and assessment of environmental impacts in agrarian landscapes. These modules are represented by several single assessment algorithms or models and form the landscape model by various input- and output-connections among each other.

The prime objective of the most landscape models is to create an integrated approach to economic and ecological processes in a watershed. Figure 6.4-5 shows an example of an integrated ecological-economic modeling and evaluation framework. The objective of the study determines very much the spatial, temporal and structural resolution of the model. The following parts show the structure of a landscape and related topics on the example of the Patuxent watershed model (Voinov et al. 1999, http://iee.umces.edu/PLM).

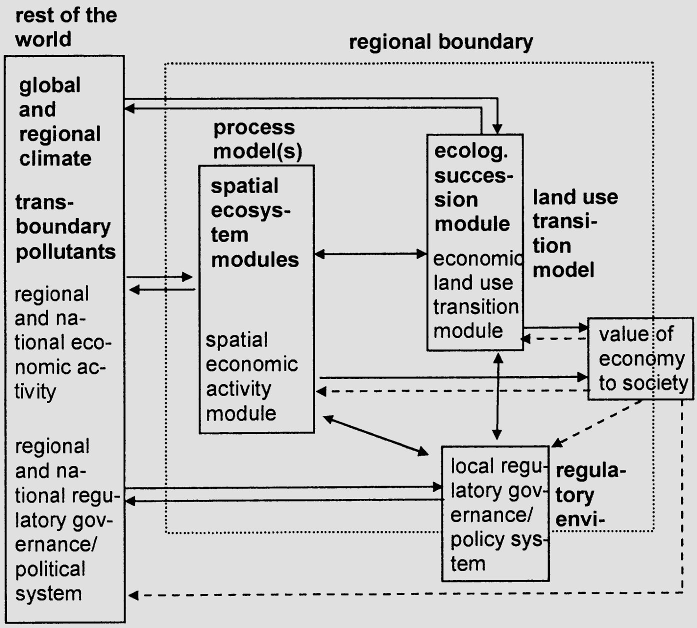


Figure 6.4-5: Integrated ecological-economic modeling and valuation framework: driving forces, initial values and series of measurements (http://iee.umces.edu/PLM)

In the spatial domain it has to be assured that the ecological, hydrological heterogeneity in the area can be represented as well as the socio-economic heterogeneity. Two types of **spatial design** have been mostly used in watershed modeling:

Lumped network based units: the whole area is subdivided into regions based on certain hydro-ecological criteria. These may be subwatersheds of certain size, hillslopes, areas with similar soil and habitat properties, etc.

Grid-based units: the landscape is partitioned into a spatial grid of unit cells. The cells may have different size but their geometry is the same. This approach allows cell attributes to change during the model run.

Table 6.4-2: The thematic modules of the landscape model "Kraichgau" (Dabbert et al. 1999)

thematic module	description
module nitrogen	soil-related description of the potential risk of groundwater contamination by nitrate input
module erosion	soil-related description of the potential risk for soil denudation by erosion
module economy	illustration of the impact of agrarian policy on agricultural companies (farms) (close sectors)
test modul farm modeling	estimation of changed boundary conditions on companies (farms) (local levels)
module nitrate	description of the nitrate loading in dependence to the cultivation practice
module nutrient input	modeling of the nutrient input in biotopes
module area-relation	generation of area-concrete data from aggregated data

One possibility for the **temporal design** of landscape modeling is the definition of fixed time steps according to the goals of a study, e.g. they have to be long enough to illustrate the impacts of political decisions by models or limited by the temporal borders for assumptions on economic structure and development. Other approaches assume that in time it is possible to represent the system as a sequence of independent discrete events.

With respect to **structural design** we have to state that landscape models are more and more process-based. The processes considered are mostly related to climatic conditions, hydrology, nutrient movement and cycling, terrestrial and estuarine primary productivity, and decomposition, etc. As mentioned in Chapter 6.4.3, the hydrologic processes are fundamental for the models, simulating water flow vertically within the cell and horizontally between cells. Nutrients cycled through plant uptake and organic matter decomposition, etc. The model should incorporate a modular structure. This allows individual modules to be designed and tested independently, prior to running the full model with all modules. Figure 6.4-6 shows an example of the structure of a landscape model. A landscape model is not a "universal model" but a "meta model" which holds a multitude of very different modules in a model bank.

The success of **model calibration** is very much dependent upon the available data. Calibrating and running a model of this level of complexity and resolution requires a multi-stage approach (see Chapters 6.4.3 and 6.4.4). However, from a scientific point of view the **validation** of dynamic landscape models is awaiting a satisfactory solution to the problem caused by lack of available high-resolution data, as well as by a lack of suitable strategies for the validation of complex models. Wenkel (1999) points out that an ensemble of methods could lead to a solution of the problems.

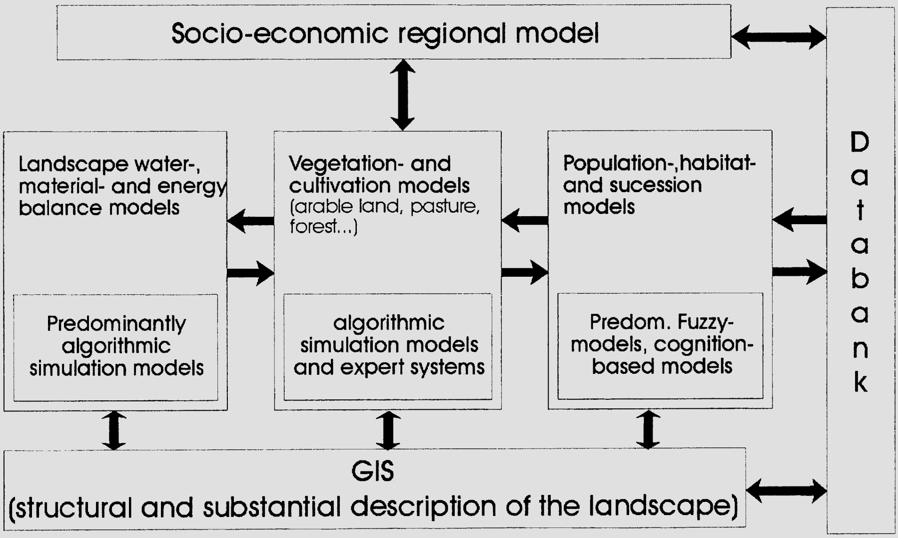


Figure 6.4-6: Main modules of a the dynamic landscape model „MLM“ (after Wenkel 1999)

6.4.7 Conclusions and outlook

There is an obvious trend from the development and application of single models to the development of integrated dynamic landscape models holding a multitude of very different modules in a model bank. Landscape models aim at the analysis and assessment of medium- to long-term ecological and socio-economic consequences of human caused landscape changes. Landscape ecology is understood as an inter- and transdisciplinary scientific branch (see Chapter 1.3). That means that an instrument trying to consider the landscape ecosystem from a holistic perspective and bridge the methodological and technical difference between scientific disciplines can only be developed in a multidisciplinary cooperation of many scientific fields. Due to Wenkel (1999) the future progress in landscape modeling will depend particularly on the success of unite theoretical and experimental ecologists with system analysts, computer scientists, and socioeconomists. Beside many scientific and technical open questions, some complex problems have to be solved in the future (Wenkel 1999, Volk & Steinhardt 2001).

Chapter 7

Application of landscape ecology

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7.1 Landscape ethics and sustainability

7.1.1 Introduction

The language game of landscape ecology entails several action-guiding verbs like "promote", "enhance", "restore", "preserve", "safeguard", "ensure", "upgrade" to name just a few. They are closely related to conceptions of what should be done. Due to this evaluative and protective character of landscape ecology and due to its connectivity with evaluations, planning, and decision making it seems urgent to add philosophical and ethical considerations to the overall transdisciplinary research program of landscape ecology. Due to the multi-facetted concept of landscape these considerations should be performed in a more reflective way. It is quite trivial to say that humans are responsible for the regions they inhabit since they are designing and planning of how to modify landscapes according to their objectives and values. The notion of responsibility is intrinsically related to values, obligations, and principles which are debated in ethics. These categories will be analyzed in Chapter 7.1.2. In a further step the underlying ethical aspects of different disciplinary perspectives will be outlined (see Chapter 7.1.3). At the end of this investigation it shall be asked how different perspectives are related to each other. Additionally, the relationship between landscape evaluation and the concept of sustainability will be explored (see Chapter 7.1.4). In a final section, it will be pointed out how the rightness of procedures and the goodness of outcomes are related in cultural debates about

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how to take responsible care of landscapes (see Chapter 7.1.5). It will be argued that a highly democratic and discursive approach in landscape planning could provide "good" outcomes if some general insights of environmental ethics are presupposed and taken seriously.

7.1.2 Ethical values, obligations and paradigms

In ethics, the theory of values is called axiology. The theory of obligations is called deontology. Environmental ethics is one field of practical philosophy (“applied ethics”). The notion of value may serve as a starting point of analysis. One can distinguish three axiological paradigms: 1. idealistic ("Platonic") paradigm, 2. naturalistic (or realistic) paradigm, 3. preference-based paradigm.

In the **idealistic paradigm** which goes back to ancient philosophy values are regarded as ideal entities which are located in a sphere of pure validity. Thus, this first paradigm rests on strong assumptions which are hard to defend in contemporary philosophy. Among others, Mackie (1977) has criticized both the ontology of a separated realm of ideal values and the epistemology of a special faculty called "intuitus" by which one can have insight into this realm. A Platonic account in landscape evaluation would have to "double" any landscape into an everlasting idea. There is no reason to believe that any landscape has an ideal double. This idealistic paradigm has to be rejected for several philosophical reasons.

In the **naturalistic paradigm** values are regarded as properties (or features) of natural or cultural objects. This paradigm had been rejected since the enlightenment but it has become quite influential in environmental philosophy mainly due to the work of Rolston (1988). According to him there are non-experienced and therefore "absolute" values in nature. Value judgments are then to be regarded as a certain kind of factual judgments. "We need to think of value judgments as genuine (...) claims about the world" (Rolston 1988). One reason against naturalistic approaches in axiology shall be mentioned. If one distinguishes primary, secondary, and tertiary qualities of entities, primary qualities are real. They are the proper objects of physics and chemistry. Secondary qualities as colors are intrinsically related to perceptions. Tertiary qualities are supervening to both first and secondary qualities. (One is free to like or to dislike the colors one perceives.) Tertiary qualities are interpretations of perceptions according to some underlying preferences, interests and cultural standards. If so, it seems to be a categorical mistake to naturalize values. This mistake would be repeated in a naturalistic landscape evaluation. Values are not parts (properties, features) of a landscape but parts of a landscape might be valuable to human subjects.

In the third axiological paradigm the basis of valuation lies in the difference between favorable and unfavorable states of the mind ("**preferences**"). A human subject assigns ("attributes") some value to something according to her preferences and according to value-standards she once has adopted. Preferences are "first-person"-information. The basic assumptions of this paradigm are similar to those being made in an economic perspective. The basic terms are "good" and "bad". "Bad" simply denotes a negative preference: "Something is bad for me." "Good" and "bad" might be specified by any of the axiological attributes which are used in ordinary language. The intensity of valuing something can be expressed by those attributes. The term "good" has an axiological, not yet a moral meaning.

The **conceptual advantages** of this paradigm are the following:

1. This approach has a large scope of applicability.
2. There is nothing puzzling about values in this paradigm. Valuing is an essential part of our daily life.
3. Everyone is free to value matters as one really feels about them ("authentically"). Landscapes can be judged as being "nice", "richly structured", "marvelous", "boring", "ugly", "admirable", and the like. Single newly introduced elements like buildings or roads can, for example, be judged as "fitting" (or not). In judgments about landscape modifications, we use axiological attributes like "fitting", "disturbing", "enriching", "impoverishing", and "(dis)harmonical".
4. Experimental psychological studies or economic techniques of landscape evaluation can be integrated in this paradigm without conceptual difficulties. Moreover, factual evaluations might be traced back to underlying cultural conventions of how to take care and make use of landscapes (Nassauer 1997).
5. This paradigm fits well into the plurality of aesthetic taste which characterizes our modern situation.
6. One gets a clear analytical approach towards value-judgments. A subject (S) judges some feature (f) of some entity (x) (or the entity as such) as valuable (v) according to some standard (s). One can transform this basic structure into a (ordinal) betterness-relation: S judges something (f(x) or x) as being better (>) or as being "at least as good as" (≥) than something else. Details of analysis are given in a logic of preferences. This axiological paradigm encompasses even "deep" values like "feeling at home", "enjoying otherness", "being anchored or transformed", "appreciate beauty", "admiring the grand scenes", "meditating the sublime", "feeling awe", and the like.

Some **consequences** of this axiological paradigm have to be accepted. There is, first, no conceptual space left for "absolute" values of nature and landscapes independently of conscious valuers. Second, a cultural plurality of preferences, conventions, and standards must be accepted. Third, one is always at some pain to explain why some value judgments are "better" or "worse" than others. Fourth, the gap between values and obligation must be bridged.

In axiology and in environmental ethics several proposals have been made to categorize values. The most common distinction has been made between instrumental and intrinsic values. Instrumental values are part of a mean-end-relationship: something is as a mean (instrumentally) "good" or "bad" for something else. The existence of intrinsic values is conceptually entailed in the idea of a mean-end-relation since the chain of means must come to an end at some practice or state of affairs which are as such ("intrinsically") valuable. It would be absurd to imagine a world full of means without any final ends. There are four **categories of values**, which are coined as follows:

1. anthropocentric instrumental values ("good" as means for humans),
2. bio-related instrumental values ("good" for non-humans),
3. eudaimonistic intrinsic value ("good" as ends for humans), and
4. inherent moral value respectively "moral standing" ("end in itself").

In the field of environmental ethics, the first category is closely related to the notion of a natural resource. Bio-related instrumental values are values which are functional "good" for some non-human beings. The category of eudaimonistic intrinsic value often has been confused with the category of inherent moral value. There are two different meanings of "intrinsic" "**eudaimonistic intrinsic value**" and "**inherent moral value**". Obviously, something can have eudaimonistic intrinsic value without having inherent moral value. The former category applies if human beings value some thing or some activity as being good for them "as such". The classical examples of such activities have been friendship, play, enjoyable activities or the experience of pieces of art. This category is related to the idea of an undiminished "good human life". Eudaimonistic intrinsic values often are related to more refined human interests, appreciations and desires. Aesthetic, recreational, scientific, transformative and spiritual values belong to this category. Hampicke (2000a) and Krebs (1999) argue that these values have been severely underestimated. All persons who value unspoiled nature and natural environments are treated recklessly by the destruction of more natural landscapes (Figure 7.1-1). This kind of recklessness matters morally. The category of inherent moral worth will be debated on the next page.

Types of values should be seen as a next step in order to operationalize the categories of values. The types which are crucial for the valuation of landscapes are the following (Kellert 1997, Krebs 1999, Rolston 1988):

- Life Support Values,
- Option Values or Insurance Values,
- Social Amenity Values,
- Aesthetic Values,
- Recreational Values,
- Scientific Values,
- Historical Values or Bequest Values,
- Transformative Values, and
- Religious and Spiritual Values.

To comment on all these types of values would result in a comprehensive axiology of nature which is clearly beyond the scope of this chapter. As it shall be shown in Chapter 7.1.3, different perspectives in landscape ecology are rooted in and centered on certain categories and types of values.

Figure 7.1-1: It is a basic question of ethics: Are there intrinsic and inherent values in (natural) landscapes? – High mountains scenery in the Retezat Mountains (Romania) (Photo: O. Bastian 1982)

Moving from axiology to deontology one has to argue what kind of features of landscapes should be protected for which axiological or moral reasons. It will be assumed here that obligations to future generations in regard to natural environments should be respected morally. This gives the concept of a fair intergenerational bequest package. The content of such bequest package will be discussed in Chapter 7.1.4.

The ethical debate about the category of **inherent moral value** belongs to deontology. It is asked which beings are to be regarded as "ends in themselves" and, thus, are considered for their own sake. This question might be called the "inclusion"- or "demarcation"-problem of the moral community.

The answer one gives directly implies a certain position in environmental ethics (anthropocentrism, patho-, bio-, ecocentrism, or holism). The different positions about the scope of beings which "own" moral value or “have” moral standing have paramount impact to conflicts in landscape planning because inherent moral values normally can't be negotiated. Any grading of inherent moral value bears the burden of proof.

The justifications which are given in regard of inherent moral value must entail assumptions about moral relevant features or capabilities. One has to argue why some feature should be regarded as a morally relevant feature (rationality, interests, sentience, being alive, existence, naturalness, and complexity). Arguments must be made according to well-established logical and meta-ethical standards of reasoning: without committing the naturalistic fallacy, without a petitio principii, without purely arbitrary assumptions and not by definition only. One should not expect that such arguments will be a definite proof. But there are degrees of plausibility.

With some caveats, a mainstream-position in environmental ethics is pathocentrism ("sentientism"). **Sentientism** can successfully avoid to commit the naturalistic fallacy since pleasure and pain are not just matters of fact "out there in the world" but are perceived and felt "from inside". Sentience matters morally since it conceptually implies a perspective onto the world. According to this solution of the demarcation-problem humans have direct obligation to sentient creatures only. **Biocentrism** takes one step further. Taylor (1986) argues that one should take the attitude of moral respect to all living beings since, first, living beings are striving in "telos"-oriented ways and, second, one should adopt a "biocentric outlook on nature" in an ideal situation of choice between competing world-views.[3] Attfield (1999) argues in favor of biocentrism that beneficence is central to morality and that all entities which have a good of their own are capable of being benefited. Such arguments are appealing to the widely shared intuition that life is "something special" which should not be destroyed without reason. But these arguments have to face severe criticism. Krebs (2000) argues that teleonomical structures have to be seen as machine-like behavior which has no moral significance at all. Wetlesen (1999) recently has argued for a more modest version of biocentrism. A biocentric attitude towards life (Schweitzer: reverence for life) can and should be part of one's individual moral (and not just eudai-

[3] But the argument Taylor gives for adopting this biocentric outlook on nature is confused by circularity since one decisive condition of choice ("reality awareness") has been already defined in terms of the "biocentric outlook on nature" itself. Taylor could reply that his circle is big enough to be regarded as being a "circulus fructuosus". I will not enter into debates about types of circularity here but assume that Taylors "world-view"-argument is circular in a vicious way. If so, it remains unclear why teleological (or, better: "teleonomic") behaviour deserves our moral respect.

monistic) identity but it is not strictly obligatory for everybody to adopt this attitude (Wetlesen 1999). In a modest interpretation: "gradual moral respect for sentient beings" as obligatory and "reverence for life" as part of one's own moral identity, a combination of sentientism and biocentrism might be defendable ethically.

Ecocentrism gives moral standing to biotic communities, ecosystemic wholes, or, in Aldo Leopolds terminology, to "the land" as such (Leopold 1949). It remains highly questionable of whether ecocentrism will provide a sound ethical basis for conservation biology or landscape ecology, as Callicott (1997) has argued. Ecocentrism has attracted many conservationists because of its stringent consequences, especially in regard of the preservation of wilderness. At the surface, a landscape ethics and a "land ethics" seem to be natural allies. But, ethically, it remains unclear which features of ecosystems deserve moral respect (and not just our aesthetic appreciation). There is not intrinsic moral value to be seen in evolutionary or ecosystemic processes and functions. Ecosystems have no interests at all. They can not be victimized. According to author's judgment no sound justification for ecocentrism has been given. If one rejects ecocentrism one might accept obligations **in regard to ecosystems** because of the values and services they provide to humans.[4] If one accepts obligations to sentient wildlife one has also to accept obligations in regard to their natural habitats. Varner (1998) has drawn an important distinction between practical and ethical holism. On might support practical holism in landscape ecology while rejecting ethical holism and ecocentrism.

Thus, there is a well-established axiology of environmental values which is preference-based, robust and richly textured. The deontological combination of a) respect for intrinsic eudaimonistic values, b) moral obligations to future generations and c) sentientism will provide a sound rationale for conservation, preservation, and even restoration of landscapes. This provisional result of the ethical debate can be presupposed for investigation in landscape evaluation. From sentientism it follows clearly that landscapes always have to be perceived as habitat for wildlife and not only as visual sceneries.

7.1.3 Ethical aspects of different disciplinary perspectives

Several distinct definitions of what a landscape "(really) is" can be found in the literature which encompasses a broad range of meanings from "per-

[4] Generally, one should distinguish between obligations "to x" ("gegenüber") and obligation "in regard to x" ("in Ansehung von"). The latter are direct obligations, while the former are indirect ones. We have direct obligations to members of the "moral community" only. To other parts of the natural environmental there might be obligations "in regard to". Indirect obligations presuppose direct ones.

ceived picture" to "geographical space" and "ecosystem" (Bastian and Schreiber 1994, Leser 1991b). The tensions between ecological, historical and aesthetic approaches have their starting point in competing definitions. A distinction should be made between **ontological** ("realistic"), **historical** ("idealistic") and **cognitive** ("constructivist") definitions. In aesthetics, a landscape will be constituted ("construed") by the aesthetic attitude of the experiencing subject. From an aesthetic approach is might be conceded that nature is "out there" but it will be insisted upon that a landscape is no real entity but an aesthetic category. In ecology, the ontological notion of landscape is often used as a larger scale of ecosystem analysis. As such, it is a scientific and value-free concept. Only in combination with some conservative assumptions about environmental risks, guidelines for wise use can be derived (see Chapter 7.1.5).

Despite national contrasts, the historical European definition of landscape is closely associated with the notion of visually pleasing ("Edenic" or "Arcadian") countryside (Figure 7.1-2). Landscapes are some "middle ground" of rural (agrarian or pastoral) enterprise which are located in between the wild and the urban (Porteous 1996). In landscapes, nature and culture blend. The well-known cultural ideal of landscape is connected with some eudaimonistic vision of sustained livelihood ("harmony") between man and nature. There is overwhelming evidence that we have moved far away from this ideal. It is quite fair to argue that landscapes often have been perceived as mere space for economic activities and not as genuine "places". Thus, a divergence has occurred between cultural ideals and hegemonic economic practices.

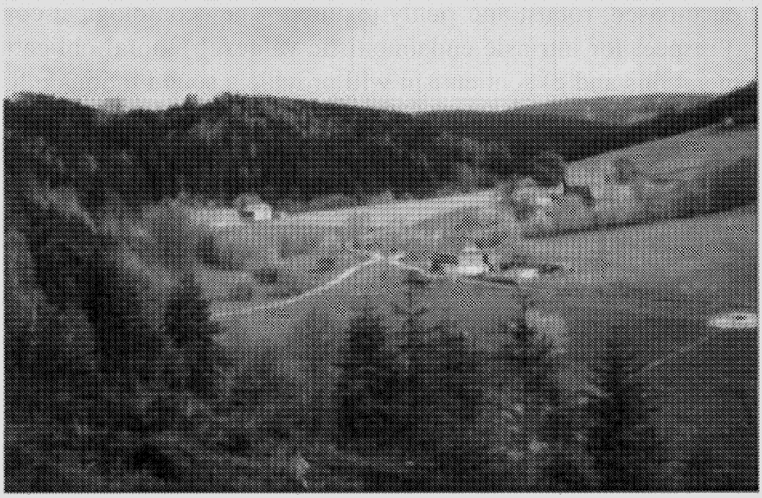


Figure 7.1-2: Despite national contrasts, the historical European definition of landscape is closely associated with the notion of visually pleasing countryside: Saupsdorf village (Saxon Switzerland low mountains, Germany) (Photo: O. Bastian 1978)

Since the notion of landscape is contested and complex several attempts have been made to distinguish perspectives and approaches. Eight different perspectives are to be distinguished. The ecological, historical, and aesthetic perspectives are "backbones" of landscape evaluation but they are to be augmented by other perspectives.

From a **first-person-perspective**, landscapes are parts of an overall human environment. The human environment is to be defined as being a field of significance ("meaning") (Cooper 1992, Dower 1993). Single artificial or natural components of such fields of significance and the interplay between components and the "whole" can be valued in many different ways according to the axiology which has been outlined in the previous section. Articulated landscape evaluations can be traced back to deeply rooted cultural conventions which are part of different cultural life worlds. Cultural anthropologists explore such life worlds. It would be a misleading ideal trying to become completely free from the conventions of one's own culture. One should better try to explicate and clarify them. This clarification would be a requirement for intercultural dialogue about the environment.

From an **evolutionary perspective**, a "habitat"-theory of landscape evaluation has been proposed by Appleton (1996). Aesthetic satisfaction is regarded as spontaneous reaction to landscape as habitat. The approach is close to biophilia-hypothesis (Kellert 1997, Wilson 1984). Psychological evidences for deeply rooted preferences for savannah-type-landscapes provide some empirical and theoretical support to evolutionary approaches. This evolutionary perspective has to explain the fact that modern humans are experiencing landscapes aesthetically which - as deserts, tropical forests, high mountains, mires, snow regions and the like - are not well suited for human habitation. Such explanation seems possible. As Immanuel Kant noted in the "**Kritik der Urteilskraft**" the aesthetic perspective presupposes some acceptable degree of security. If this degree of security can be guaranteed the more aesthetic attitude towards landscapes may evolve culturally far beyond savannah-type-landscapes.

From the **perspective of cultural anthropology and history**, certain regions are enduring habitats of certain human populations. As such, they are both constraints and enabling conditions for culture. As it was recognized in the "climate theory" since Montesquieu which had been adopted in Germany by J. Möser, G. Herder, and E.M. Arndt, cultures and natural environments are shaping and modifying each other mutually. Certain landscapes are results of such mutual shaping. Details of this shaping can not be deduced by universal laws but must be told in narratives. Thus, stories must be told if the history of a landscape is to be understood properly. But without any axiological or normative premises the history of a landscape consists of matters of facts only. The values of the people under investigation shall not be confused with normative claims of contemporary persons including historians. There are several options to introduce values into the historical perspective.

One may presuppose the Western ideal of a landscape and confront it with reality. Another option is being given by the notion of **age**. "Age" as such is no moral value but it belongs to the type of historical values. Some old entities in the world are of value for many people just because they have survived the processes of ongoing modernization (see Chapter 7.8). Landscapes and certain landmarks are giving visual evidence that "something remains". This argument will result in a "nostalgic" or "monumental" justification for landscape protection as it has been given in the German tradition (Ott et al. 1999). Today this justification is conceptualized as bequest-value-argument. In our civilization of increasing mobility, economic globalization, intellectual cosmopolitism, technological innovations and virtualization ("cyber space") it seems reasonable to put some bequest value on traditional landscapes. Landscapes are to be perceived as being heritages which should be bequeathed towards our descendants. This "ethic-cultural" approach would imply that humans should take the role of cautious stewards of the natural environments they inhabit. This stewardship-approach will be supported by Christian environmentalists since it is the most reasonable interpretation of the Biblical prescription to "subdue" nature (Genesis 1, 26) which in its original meaning is not "dominionistic" at all. Such notion of culture also would mean that humans should enrich their natural environment, make it more suitable and beautiful. This argument directly leads to the overall concept of sustainability (see Chapter 7.1.5).

In the **romantic tradition**, the notion of individuality ("organic whole") was extended and applied to landscapes at the beginning of the 19th century. This extension was relevant for the constitution of landscape ecology. A. v. Humboldt (1836) defined a landscape or region by its "total individual character" (see Chapter 1.1). A whole language game rests on this extension since landscapes now can be perceived as having a "character" or an "integrity" which can be distorted, hurt, wounded and even destroyed. If one argues that a landscape should "keep its face" or should be restored to its former identity one argues from the inside of the "idio-logical" (individual-centered) paradigm of thinking. If humans act on the environment they are not just using resources instrumentally but they are treating a historical individual. Like individuals, landscape can be treated badly and, therefore, be wronged. What kind of speech acts will count as arguments in landscape valuation will depend on Humboldt's extension? Under some idiological presupposition it becomes more reasonable to think of landscapes as entities which should be protected and kept intact "for their own sake". Historical individuals are not just of instrumental value but must be valued intrinsically. Since they have individuality in a strong sense, they might even have some inherent worth. Philosophically, it remains unclear of whether landscapes can be perceived as historical individuals in a strong sense. The differences between individual persons and systemic natural wholes seem to outweigh some superficial similarities and analogies.

It has been recognized by many contributions in environmental ethics that aesthetic arguments provide a rationale for the preservation of landscapes. An eco-centric critique of aesthetic arguments as "instrumentalism" can not stand detailed investigation (Cooper 1998). From an **aesthetic perspective**, landscapes are spaces of perceptions of natural and cultural beauty (see Chapter 5.5) . The aesthetic attitude is constitutive of the phenomenon of a landscape. There is no landscape without aesthetic perception. This notion of landscape is connected to the notion of beautiful scenery. Many historians have argued that the aesthetic sense for natural beauty evolves parallel to the domination of nature. The more persons get aware of the growing difference between nature and civilization, the more they are enabled to perceive more natural landscapes aesthetically.

According to J. Ritter a landscape is nature which is aesthetically perceived (Ritter 1963). This definition implies that landscapes only come into "existence" if humans encounter nature without any practical purposes. The only purposes at stake are to enjoy nature as landscape and to be as oneself ("freely") in nature. To Ritter, the aesthetic point of view is also a reminder for the ancient metaphysical "theoria" of the "kosmos". Ritter combines this approach to landscape with a Hegelian account to modern industrial society which alienates individuals from traditions. The aesthetic experience of landscape is also a compensatory substitute for a lost "ethos". Ritter's approach is still inspiring but it has severe shortcomings (Groh and Groh 1991, Ott 1998, Seel 1991).

Different modes of aesthetic experiences have been analyzed by Seel (1991). They can be of a kind of contemplation of natural entities, or a correspondence with life prospects, or imagination in close relationship with works of art. To Seel, the notion of landscape is intrinsically related to an uncoerced interplay of these three different modes of aesthetic experience of nature. The aesthetic notion of landscape is intrinsically connected with the eudaimonistic idea of a good and flourishing human life. This opens a direct route into morals. Seel argues that there are moral obligations to protect more natural landscapes in order to protect opportunities for aesthetic experiences which are of paramount importance for a good human life. Seel's argument is convincing but it doesn't have strong implications for the preservation of species and ecosystem components.

The cultural relativity of aesthetic landscape evaluation has been explored since Riehl (1850). From the beginning of preservation it had been contested of whether and how aesthetic concerns could be incorporated into law (Heyer 1912). Since it has been required by law in many states that landscape sceneries should be protected several concepts and schemes have been developed to make aesthetic perceptions of landscapes more "objective". Criteria for the assessment of the visual character of landscape elements are to be found in Krause (1996), Nohl (1998) and in Chapter 5.5. Humboldt's extension is implicitly presupposed here since it is assumed that "the full effect of disturbances to the visual landscape can only be determined after taking into consideration the total character of the landscape" (Krause 1996). Most philosophers will be skeptical of whether the "wit" of aesthetic experiences can be grasped by such "objective" methods. If aesthetic experiences are related to an uncoerced interplay between rationality, cultural standards and imagination, this performative interplay will not be cached by such methods. At the moment, such concepts are hybrids between visual schemata, theories of environmental psychology, geoecological data and idiological background-assumptions.

In **economics**, some approaches have been presented to evaluate landscape change (Santos 1998). To economics, landscapes are common goods. From an economic point of view any preference including the preference for the protection of common goods must be confirmed by some willingness to pay (Hampicke 2000b). Economists will use the methods of contingent valuation and of travel cost analysis to measure the explicit or the revealed preferences for certain landscapes and the willingness to pay for their preservation or restoration. These techniques only register factual preferences independently of whether these preferences are ecologically well-informed or not. Thus, the ecosystem services might be underestimated and adjustments must be made. Future preferences can not be registered by these methods. These caveats kept in mind, "contingent-valuation"-studies provide useful insights. The contemporary existing level of the protection of nature is, on the average, less than such studies indicate as demand.

The preference-based approach in economics will be rejected as superficial by a presumptive "deeper" **psychological perspective** which often will be relied on C. G. Jungs doctrine of archetypes. Archetypes of the human mind (better: spirit, soul) are rooted in landscapes and, on the reverse, landscapes are mirrors of the human spirit. The argument runs as follows: It is assumed that these symbolic connections are more alive in traditional cultures and that members of traditional cultures are more akin to them. At a profound level the interrelationship between humans and landscapes should be seen as a symbolic and spiritual encounter which has been distorted and denied in our modern culture. But the logic of symbols and myths is inescapable (Figures 7.1-3 and 7.1-4). Because we are ignorant about this logic our destructive energies (Freud, Marcuse) take command of our behavior towards nature. Thus, we should take symbolic "Gestalt"-experiences as a genuine mode of how to encounter landscapes. If the argument is sound, the historic and aesthetic perspectives should be augmented by a deeper psychological and spiritual one.

From the **perspective of a scientific ecological observer**, landscapes are complex and "netted" hybrid unities of natural and cultural environments. They are based on geological formations, shaped by climatic factors, filled with biotic communities and, mostly, modified by human action. From this perspective, modifications of landscapes can be described, explained, and assessed. This can be, in principle, a value-free enterprise which describes "what's going on". Connectivity is a basic ontological assumption and, thus, an epistemic, not a normative principle. Thus, the gap between facts and values must be bridged in ecology. For this purpose, normative criteria have to be introduced (diversity, rarity, naturalness, representativity, species richness, and the like) and have to be weighed. The axiological significance of these criteria often is weighed according to the general targets of conservation biology (protection of species and types of biotic communities or ecosystems). Both the criteria and their weighing must be justified ethically. Doing so, one notices both convergences and divergences among conservationists. One might also use the concept of the **ecological potential** of landscapes (see Chapter 5.2) for normative orientation (Succow 2000).

Figure 7.1-3: Mt. Fuji has an extraordinary high ideal value for the Japanese people (Photo: O. Bastian 1993)

If these criteria of conservation biology are operationalized one can put some numbers on concrete landscape elements and, thus, also quantify compensation which must be made according to impact mitigation regulation. This operationalization approach has been designed to highly sophisticated concepts (Plachter 1994). These concepts are to be accompanied by some caveats in regard of the production of numbers. A reasonable discursive justification can not be replaced by quantifying.

These **different perspectives are like lenses** according to which landscapes are perceived, valued and judged. They are not layers of an hierarchy. They must be distinguished analytically but they will be combined in several ways. The historical, the aesthetic and the idiological perspective have been combined from the beginning of the preservation movement in the 19th century (Rudorff 1880). It is of paramount importance for landscape planning to relate different perspectives to each other and explicate the normative assumptions which are embedded in such perspectives. These perspectives can not be reduced to each other (Eaton 1997). There is no all-inclusive or "overwhelming" perspective. A true synthesis of these perspectives seems impossible since it would be a God's eyes view upon landscapes. However these relationships might be determined in detailed investigation, the plurality of perspectives has not to be accepted "nilly willy" but it should be positively affirmed since it provides opportunities for mutual learning and since it opens a space of debate and judgment formation.

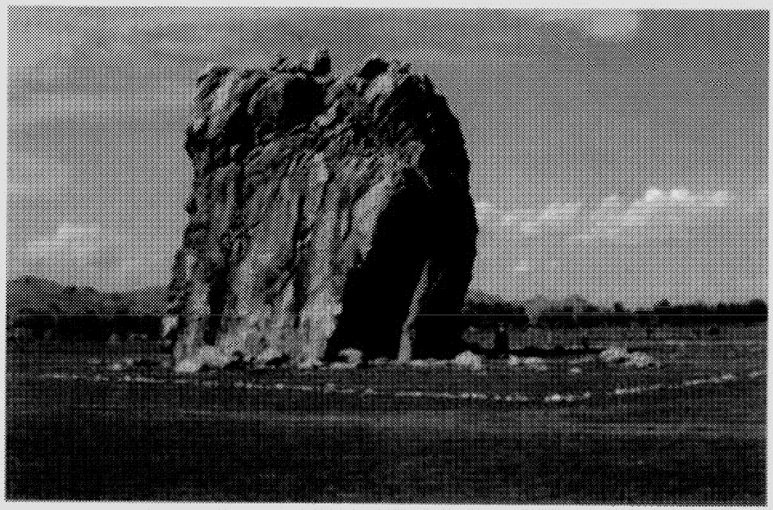


Figure 7.1-4: There are places and objects in many landscapes having mythological importance in peoples every day life like this rock in northwestern Mongolia (Photo: O. Bastian 1997)

The tensions between these perspectives have to be met in landscape planning **practically** (see Chapter 7.3). There are no moral reasons to treat all perspectives equally in each case. As it has been claimed in some articles (Carlson 1979, Eaton 1997, Finke 1986, Nassauer 1997) the ecological perspective should be a superior one. It should inform and govern other perspectives. This means saying that different perspectives are complementary but should not be of equal significance for landscape planning. This primacy-of-ecology-claim can be supported by arguments which indicate weak points of other perspectives. The first-person-perspective is biased by conventions. The evolutionary perspective will be ignorant about ecological processes at both minor and major scales. The economic perspective is preference-oriented and, thus, might be blind to ecological services and moral obligations. The idiological perspective rests on a questionable extension. The psychological perspective remains, at least in part, speculative and, regretfully, often affirms highly metaphysical assumptions ("genius loci") and pseudo-sciences. The aesthetic perspective might be blind to ecological processes which can not be perceived directly. Some non-perceivable facts are crucial in landscape ecology (Eaton 1997). Moreover, there might be biases in the aesthetic lenses which result from too close a contact to works of art. Aesthetic ideals of the past should not dominate contemporary landscape evaluation.

It has been argued that scientific knowledge should inform aesthetic perception of nature. Originally, the argument was made by Alexander von Humboldt against Edmund Burke. One can, of course, appreciate a songbird or a flower aesthetically without knowing their species-name, their taxonomic relationships and their evolutionary history. Humboldt conceded this trivial point to Burke. But this point is not at the core of the argument. At this core there is the presumption that one, in general, will appreciate nature deeper the more one knows about it. This spiral-like relationship can not be reversed. Thus, one can subscribe to the point of view that on the level of landscape planning, there should be some primacy of ecology over aesthetics. If this primacy is restricted to landscape planning there is no danger that the autonomy of aesthetic perception might be restricted on the level of its very performance itself. This primacy of ecology over aesthetics can not be reversed since it is less obvious that aesthetic landscape planning would encompass ecological objectives. "We should construct a kind of cultural necessity to underpin ecological health across the landscape, as if there were no other choice" (Nassauer 1997).

7.1.4 Landscape assessment and the concept of sustainability

The **notion** of sustainability (see Chapters 7.3.1 and 7.9.2) has to be regarded as an ethical idea which is founded in moral obligations towards future generations. The underlying idea of intergenerational equity is debated in ethics. This idea might be explicated in terms of "future needs", "entitlements", "an undiminished stock of resources", "non-declining utility", "equal opportunities to access", and the like. Most ethicists would agree to a definition which emphasizes the moral right of an average future person to find opportunities to realize his/her concept of a good life which, on the average, should not be worse than the opportunities for contemporary persons. This definition combines a deontological right-based-morality which has been enlarged intergenerationally with a broadly defined teleological objective and some modest assumptions about a "good human life". Sustainable development is development which tries to reach a sustainable state or, if such a state has already been reached, tries to maintain it. This definition of sustainable development avoids the confusion which is due to the murky notion of development.

Having committed to this ethical idea a decisive choice between **general concepts** has to be made. At its very core, the crucial conceptual controversy between **weak sustainability** (WS) and **strong sustainability** (StS) is about the structure of a fair intergenerational bequest package and, thus, about range and limits of substitutability. WS argues in favor of an unstructured bequest package which must be maintained on the aggregate only. Natural and artificial capitals are seen as close (or even perfect) substitutes. WS assumes that natural capital can be substituted adequately by artificial kinds of capital. The depreciation and degradation of natural capital is permissible if artificial capital will be built at the same rate. Therefore, natural landscapes can be modified if the overall stock of capital does not decline. To WS, the loss of the countryside is not too big a tragedy if the countryside can be substituted by virtual reality. Elements and components of landscape might be traded off.

StS, as proposed in the work of Daly (1996), assumes that the human sphere is embedded in a natural system whose laws must be accepted as constraints. The range of substitutability between types of capital is limited. The burden of proof falls on the supporters of substitution. The relationship between natural and artificial capital has to be seen as complementary (in a broad sense). StS argues in support of a constant natural capital rule. It emphasizes the diagnosis that **natural capital** has become scarce and, probably, will become the limiting factor for economic production.

The policy suggestions of both concepts differ. Among other suggestions, StS proposes that developed societies should invest in natural capital. To StS, investing in natural capital is essentially an infrastructure investment on different scales. While WS allows that natural capital might decrease if artificial capital will be built up StS suggests that society should invest in natural capital. This is a difference that clearly makes a difference also for landscape evaluation.

Some arguments have been presented in order to make a reasonable choice between both concepts. To critics, WS rests on the substitutability-premise which is rather strong from an epistemological point of view. One argument against WS runs as follows: If substitutability has to be seen as an hypothesis, and if many ecological systems provide several kinds of functions, amenities and services adequate substitutes must be found for every single function. To say the least, it is highly uncertain of whether such substitutes can be found. If responsible decision-makers should better err on the side of caution in matters of paramount importance to future generations, societies should adopt a constant natural capital rule as yardstick and guideline for decision-making. The multifactoral nature of ecological systems, the uncertainties about substitutes, and caution in regard of possible irreversible damage allows for a judgement in favor of StS. This argument is accepted as being sound by a growing majority of scholars who work in the theoretical dimension of the sustainability-debate. If the argument is accepted a free-standing rationale for adopting SS has been given.

The notion of natural capital which is at the heart of the SS-conception comprehends resources as freshwater, soil, forests, fisheries, ozone layer, climate system, biodiversity, ecosystem services and functions, genetic material, and units of cultural significance. Landscapes are regarded as being "units of significance" (Holland 1994) and, as such, are components of the contested category called "natural capital". It seems intuitively worth to protect the beauty of natural landscapes, the different ecological functions and services it provides, traditional patterns of land use, diversity and species richness, its "representativity" which makes a landscape a good token of a valuable type of ecosystem.

7.1.5 Cultural debates: How to take responsible care of landscapes?

Discourse-oriented ethical theory ("discourse-ethics") claims that the notion of the validity of any norms of action is intrinsically related to the idea of an uncoerced agreement in an ideal speech situation (Habermas 1983). The very core of discourse-ethics comprehends the derivation of a moral principle from presuppositions of practical argumentation seen in conjunction with some other premises and with a certain understanding of what arguing really means (Gottschalk-Mazouz 2000, Ott 1998). It is assumed by discourse-ethics that the contemporary moral challenges shall be addressed by means of discourse. Under modern conditions argumentation is the best response-strategy available. This will be true for landscape evaluation also. Landscape planning should be part of environmental democracy.

The relationship between the core and applications of discourse ethics is to be construed as a **multi-tiered approach** which conceptualizes discursive and participatory arrangements for public and democratic judgment-formation. Discourse-ethics assumes that all persons have, among other types of rights, rights to participate in public debates about moral, legal and, genuine political affairs (Habermas 1992). Performing these rights means, ideally, to take the role of a citizen which has to be distinguished from the consumer perspective. While the consumer tries to maximize his/her personal welfare a citizens takes interest in a solution which is “good for all being concerned”.

The general relationship between the ethical idea of a moral discourse and real discourse-oriented and participatory arrangements is both **specification** (in the "ideal-to-reality-direction") and **approximation** (in the "reality-to-ideal-direction"). Moral judgments must fulfill the requirement of being universalizable. This requirement does not hold for axiological and aesthetic judgments. Since landscape evaluation is more about cultural values, it lacks the stringency of a moral validity claim. Debates about landscapes share more features with aesthetic debates or with debates about architecture or design than with moral ones. Früchtl (2000) has argued that aesthetic discourses are crucial for the reproduction of culture and for the innovation of axiological conventions since they allow for an unconstrained interplay of different types of arguments.

Discursive approaches rest on the assumption that the protection of landscapes and the realization of ecological constraints will not successfully be reached without they people being involved. Participation could, if successfully performed, provide people with a new sense of valuing nature and landscapes. It could also make people sensitive of their environments as "heritage", "homes" and of threats to its preservation. Participatory approaches (see Chapter 7.12) will have to take serious the first-person-perspective despite of their shortcomings and conventional biases. This participatory approach has been widely adopted in the European Landscape Convention which has been signed in 2000.

But the normative yardsticks (obligations to future generations, obligations to sentient wildlife, primacy of the ecological perspective, strong sustainability) should not be denied or refuted by such participatory approaches. These normative yardsticks have been justified on higher layers on ethical debate. If we put these yardsticks into conjunction we can justify overall objectives and targets of landscape ecology and specify them according to different regions of the world by means of participatory discourse.

Some recommendations may be helpful for further debate. Since there is hardly any wilderness left in central parts of Europe specific traditional European landscapes ("Kulturlandschaften") should be preserved as heritage and, if possible, should be restored. The development of wilderness areas can be justified in regard to aesthetic, biophilic, transformative, scientific and spiritual values. The total human-dominated landscape ecosystem of Western and Central Europe should be transformed towards more ecological resilience. This is true also for the Mediterranean region which seems to be highly vulnerable to climatic change. The larger unspoiled areas of Eastern and Northern Europe should be more strictly protected. The forthcoming enlargement of the European Union should be accompanied by strategies and incentives for such protection in parts of Eastern Europe. Such landscape protection and restoration should become part of Europe's cultural identity. The concepts of "intelligent and precautionary tending" (Nassauer 1997) or "adaptive management" are next steps of operationalization. "We should use the pleasure of aesthetic experience and the social significance of care to built new aesthetic expectations that intrinsically rest upon ecological health" (Nassauer 1997). This should be seen as an ethically sound programmatic principle in landscape ecology.

7.2 "Leitbilder" for landscape development

7.2.1 Terminology

For nature conservation and landscape planning, target systems are necessary which identify the essential ecological and aesthetic objectives for a given territory (reference unit) within a reasonable short time-scale. They may be visualized as a picture (in German "Leitbild") and are an expression of an integrated view of nature conservation and landscape development. Such leitbilder are seen as providing a solution in cases where different alternatives are possible. There is, however, an ambiguous and somewhat confusing terminology in the field of environmental targets, but also concerning their application for practical purposes. Usual terms are, for example, goals, targets, principles, guidelines, visions, conceptual ideas, mission statements, objectives, and standards. General environmental principles (guidelines) can be further differentiated by so-called "objectives and standards of environmental quality". The "objectives" represent certain qualities of natural resources, their potentials and functions, which should be maintained or developed. There are thresholds and targets contained in legislation, recommended and proposed levels based on scientific understanding, and, moreover, levels which are still under discussion by scientists. The objectives are specified by "standards", i.e. they are transformed into measurable indications and values (Bastian 1998b, Table 7.2-1).

Environmental quality objectives should meet the following **quality criteria** (Gustedt et al. 1989, von Haaren 1999):

- scientific foundation: from an ecological, economic, technological and social point of view,
- transparent derivation and comprehensibility,

- orientated towards potentials, ecological carrying capacity and risks,
- clear definition and measurability of parameters and indicators,
- use of qualitative as well as quantitative parameters,
- no deterioration of the ecological situation,
- consideration of scale: global, national, regional, local,
- differentiation according to priorities and periods,
- consideration of changing environmental goals, and
- effortlessly attainable control.

Table 7.2-1: Definition and subdivision of targets in environmental planning and nature conservation (after Jessel 1994, modified)

term	explanation	examples
environmental targets/guidelines	**general aims** (higher principles) of environmental policy, without spatial and factual specification	– fundamental sections of environmental laws – targets in environmental programs
mission statements (Leitbilder) of landscape development	**higher aims**: integrative objectives of environmental quality in a special territory	– regional habitat connection – preservation of plants and animals being typical for the area
objectives of environmental quality	factually, spatially and temporally **defined qualities** of resources, potentials and functions which shall be developed in defined situations	– renaturalization of salmon in the River Rhine by year 2000 – "Within the landscape x a certain plant species shall be naturalized"
standards of environmental quality	**specific** measurable **parameters** of environmental quality (i.e. limits)	– limits for noise and harmful chemicals – classes of water quality

7.2.2 Classification of ecological targets

There are no ecological targets in the province of science only, but they need the acceptance of society. The question "How much nature do we want to have?" - is always decided politically. Natural sciences can give only advice on scientific optima which must be harmonized with the feasible ambitions of human society.

The **aim of ecological targets/Leitbilder** is to

- demonstrate a possible spectrum of objectives (e.g. from a nature conservation point of view),
- serve as a starting-point of decision-making,
- be a basis for assessment procedures and the surveillance of the efficiency measures, and

– increase acceptance and communication by clarity.

There are contradictory opinions and targets even among ecologists and nature conservationists. They vary between pipe-dreams, aims for single species or groups, and scientifically-based strategies and programs. Thus, in Central Europe the idealized pre-industrial "harmonious" cultural landscape is regarded highly (Figure 7.2-1). While striving for an optimal ecological situation, landscape functioning and high biodiversity, we must accept that the species diversity of past centuries was not the aim of human activities, but a spontaneous consequence of them. Besides a historical landscape state, other visions for a landscape, e.g. the maximization of aesthetical values, biodiversity, naturalness, the functioning of abiotic resources and potentials (soils, waters), land usability, are conceivable (Roweck 1995). The planning and management of future landscapes should take into consideration parts and principles of all these aspects.

Figure 7.2-1: In Central Europe, the idealized preindustrial "harmonious" cultural landscape is regarded highly: Village in the Mala Fatra mountains (Slovak Republic) (Photo: O. Bastian 1985)

7.2.3 Specification in space and time-scale

An essential characteristic of environmental objectives is their spatial relevance. Apart from the consideration of goals which are valid independent of the particular territory, spatially-differentiated goals in relation to attributes and functions of a spatial unit need to be identified. That means nature conservation should be realized with a different intensity and with spatial activity centers in both rural areas and settlements.

By ignoring regional peculiarities and the stereotypical application of a few basic schemes, a uniform rural landscape with a standardized biotope network would be favored. That is why spatial differentiation, and the use of spatial units dependent on scale and dimension, is so important.

When applying "Leitbilder" to **spatial units**, we need to consider the following fundamental points of view:

- Landscape visions are always related to certain spatial scopes. The specific spatial units are identified according to ecological points of view.
- The spatial units should be structured hierarchically with regard to the different planning levels.
- Landscape visions can be developed for individuals as well as for types of ecological (spatial) units.
- The smaller a reference unit, the more detailed the ecological goals must be defined.

With regard to **biodiversity**, for example, there are objectives/requirements which are valid generally (Table 7.2-2) as well as such being specific for a special region (Table 7.2-3).

Table 7.2-2: Qualitative and quantitative requirements to maintain biodiversity (species, communities and biotopes according to Heydemann 1981, Jedicke 1994, Riess 1986)

requirements	examples
preservation of all valuable ecosystems	nature reserves, protected biotopes
– protected areas	10-15% of a country's territory
– priority areas for nature conservation	additional 7-11%
– biotope patterns in agrarian areas	5%
minimum size of nature reserves	It differs depending on biotope types
maximum distances between biotopes	e.g. ponds: some 100m, woods: < 500m
preservation/promotion of	
– biotope types (being typical for a special region)	e.g. dry meadows, saltmarshes, heaths, moors
– (endangered) species	e.g. orchids, gentians, otters, cranes, capercaillies

In order to draft appropriate (landscape) ecological objectives it is necessary to consider

- the outcome of past natural and man-induced landscape change without necessarily adopting them,
- future effects of man's activities,
- single landscape factors like biodiversity (plants and animals) not in isolation, but in the complexity of the natural and transformed environment including the various interactions of man and nature.

Table 7.2-3: Aspects of targets for the landscape development - part "conservation of species and biotopes" on the example of a small landscape unit:" Small-hill area of Marsdorf" (16.3 km²) north of Dresden (Saxony, Germany; from Bastian 1998b, Figure 7.2-2)

general remarks

- protection of the rich-differentiated rural landscape character (esp. the diversity of landscape elements and ecological sites
- conservation, management, enlargement and restoration of valuable biotopes, establishment of buffer zones
- extensification of land use within the whole area
- creation of a landscape protection area

priority development of the following biotope types

- mixed oak forests on acid soils, oak-hornbeam forests, fen woods, oak dry woodlands
- dry bushes, small woodlots, sloe-hawthorn hedges
- small ponds
- moist and wet meadows, esp. the typical *Senecioni aquatici - Brometum racemosi* meadow
- mesophilic grassland as large complexes for meadow-breeding birds
- dry meadows, stone walls, field margins
- fruit orchards, extensively used arable fields

special requirement to land users

agriculture

- protection of valuable biotopes from nutrient inputs, biocides, overgrowing with shrubs, afforestation
- restoration of fresh-meadows being rich in flowering herbs
- promotion of endangered arable weeds by managing field margins without fertilizers and herbicides
- increasing diversity of land use forms and crops
- establishment of areas for spontaneous successions of natural ecosystems

forestry

- only extensive use of forests
- promotion of light forest types and structured edges in sunny positions (for reptiles)

hydrology

- renaturation of running waters
- removal of unfavorable draining facilities

settlement, industry, traffic

- no extensive growth of settlements
- no increase of isolation effects (barriers) by traffic routes

recreation

- development of only such recreation forms which harmonize with nature

With regard to **time**, two basic aspects need to be distinguished. First, the periods within which the targets shall be attained. Thus, their realization may be possible, or necessary, on a short-term as well as on a long-term basis. With regard to biodiversity development and regeneration times of ecosystems must be considered. And second, the period of validity of landscape visions is important. Generally, there is the following relation: the larger the spatial unit and the higher their hierarchical level, the longer is the period of validity of these conceptions. They must be based on the latest scientific understanding and up-to-date information about changes of landscape and society (e.g. new disturbances, other priorities). That is why, from time to time they must be adapted to new situations

Figure 7.2-2: The "Small-hill area of Marsdorf" (Saxony, Germany): The protection of the diverse rural character is a general target of the landscape development in this region (Photo: O. Bastian 1998)

7.2.4 The elaboration of landscape ecological goals - some examples

To propose management targets, the approach of assessment of **landscape functions**/natural potentials (see Chapter 5.2) is very useful. The example of several test areas in the Western Lusatian hilly region in Saxony (Bastian 1999b, 2000b, Bastian and Röder 1998) demonstrated this: in order to harmonize several targets and to propose measures for an optimal ecological future development of the landscape, an appropriate working algorithm in the form of a **decision tree** (being similar to the ecological risk assessment) was elaborated (Figure 7.2-4). Step by step, the following landscape functions were taken into consideration: habitat function, groundwater recharge, resistance to soil erosion, groundwater protection, biotic productivity (yield potential).

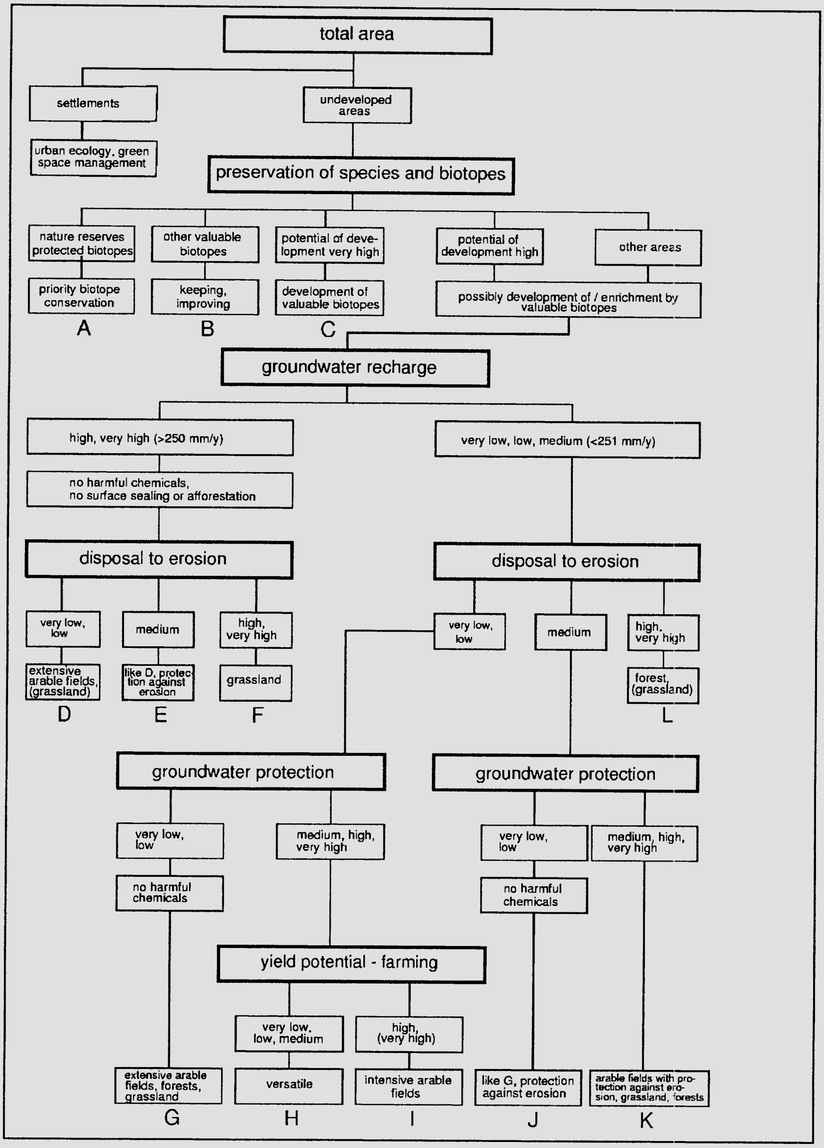


Figure 7.2-3: Decision tree for the ecological management (optimization of several landscape functions; from Bastian and Röder 1998)

This is the **working procedure**: at first, all nature reserves and valuable biotopes as well as other areas with high biotope values are mapped, in additional to sites with extreme pedological conditions (dry, moist, wet or poor soils), which could or should be developed into valuable biotopes. All these categories are to be ruled out from further consideration, because they are important especially for the protection of species and biotopes and specific measurements are necessary. After that, groundwater recharge was considered, i.e. all areas with a high rate (more than 250mm/year), with the exception of settlements and valuable biotopes mentioned above. Inputs of harmful chemicals (e.g. by intensive agriculture), surface sealing and afforestation should be avoided there. In a next step, the threat by soil erosion is considered. Areas with high (and very high) potential for erosion and high (and very high) groundwater recharge should be used as grassland. In the case of medium soil erosion, extensive utilization as arable fields is possible (while avoiding impacts on groundwater), if measures against erosion are realized.

Areas with high (and very high) erosion and very low to medium groundwater recharge should be afforested or used as grassland. With regard to groundwater protection, sensitive areas should not be impacted by harmful chemicals (e.g. biocides, fertilizers) and land use forms (industry, deposits). The remaining areas should be reserved for farming only – in the case of high biotic productivity – but a general reduction of impacts by agrochemicals is necessary and external impacts like emissions from traffic routes, old waste deposits, sewage irrigation should be excluded.

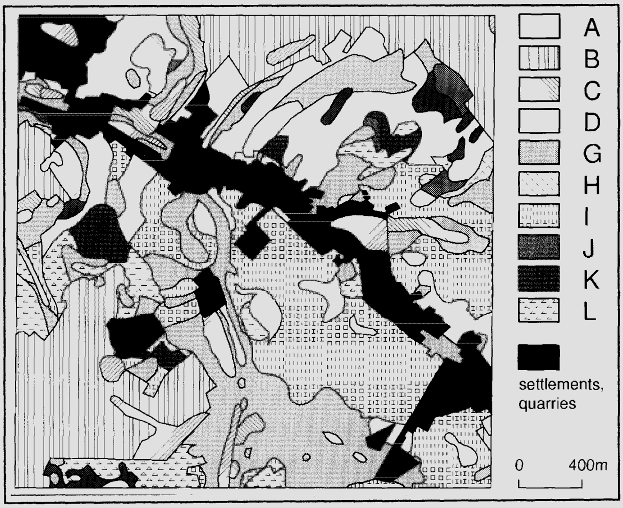


Figure 7.2-4: Proposals for the ecological landscape management in a part of the test area Steina"(see Figure 1.2-2, A, B, till K: specific measures of landscape management, see Figure 7.2-3, from Bastian and Röder 1998)

The presented approach deals ("only") with (landscape ecologically founded!) contributions for Leitbilder. It is a matter of ecological norms, minimal demands (constraints), limits of threats (impacts) and carrying capacity, which are to consider in order to enable a landscape-specific sustainable development. To achieve a consensus in the society, a broad discussion is necessary (the discursive method of finding visions of landscape development in the sense of Wiegleb 1997, see Chapters 7.1.5 and 7.12).

Usually, Leitbilder are elaborated, however, for larger areas i.e. landscape regions (e.g. Finck et al. 1997, Gerhards 1997). For heterogeneous landscape units, and the work in a **meso-scale** (= on a chorological level), the following **methodology** (approach) was elaborated (Bastian 1999b, 2000b, Figure 7.2-5):

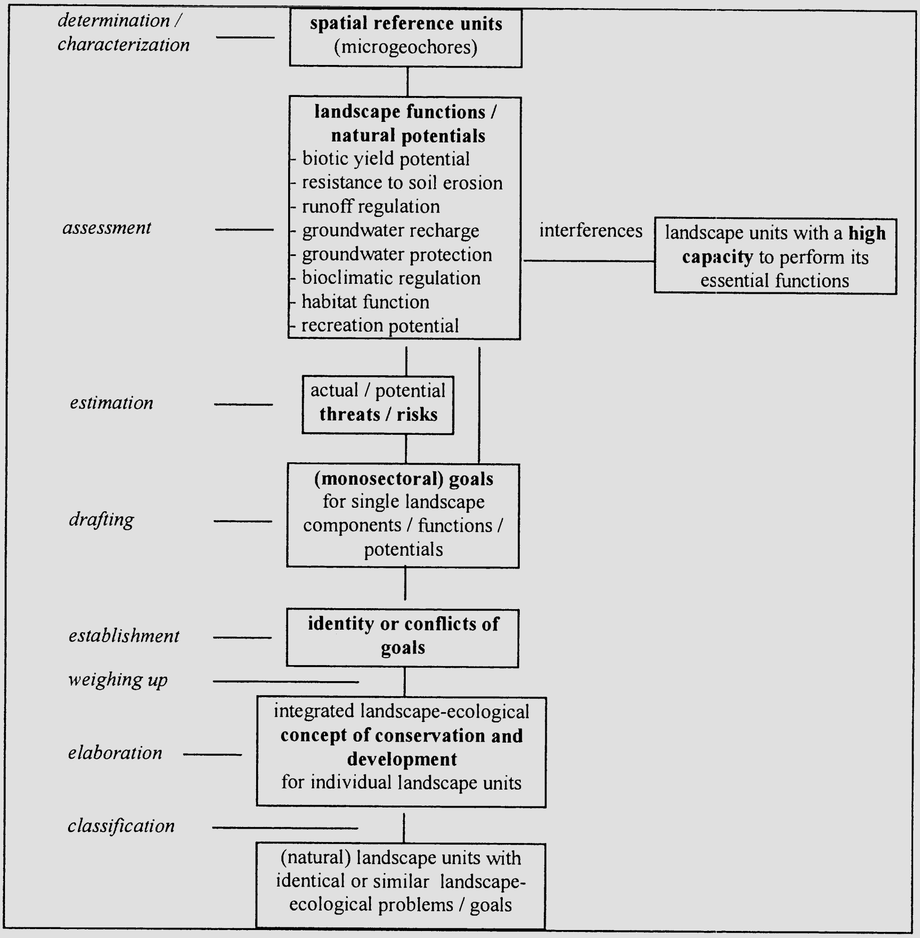


Figure 7.2-5: Algorithm for the elaboration of landscape ecological contributions for landscape visions (from Bastian 2000b)

At first, the reference units (so-called microgeochores, see Chapters 2.2 and 6.1) were delimitated, described and analyzed (data collection). Essential landscape functions/natural potentials were assessed. Special methods suitable for heterogeneous reference units were applied (see Chapter 5.2.3).

The next step includes the analysis of present and potential ecological threats/conflicts/risks caused by several human activities (esp. agriculture, forestry, industry, traffic, settlement).

On the basis of the characteristics of individual landscape units and the assessment of landscape functions, **objectives** for single landscape factors and functions are proposed (Table 7.2-4). Different extents of relevance or urgency of measures are marked. It is easily possible to specify the goals. Thus, within the complex "species and biotopes" (habitat function) target species and biotopes for individual landscape units can be defined. It is plausible that an optimization of a certain landscape function can favor or impairs other functions. For example, the preservation of productive soils for agriculture can clash with the wish to increase forest areas.

Table 7.2-4: Objectives for single landscape functions/factors in natural landscape units of Western Lusatia (Saxony, Germany; from Bastian 2000b)

landscape function/ natural potential	objectives
biotic productivity	– protection of sites with high biotic productivity for agriculture, but reduction of impacts caused by overintensification
resistance to soil erosion	– abandonment or adaptation of agriculture on sites with a soil erosion exceeding the tolerable soil loss
water retention capacity	– restoration of running waters – less surface sealing – structural enrichment of arable fields (hedges, woodlots, reduced size of fields, increased crop diversity)
groundwater recharge	– limitation of surface sealing – no afforestation – no impacts to areas with high rates of groundwater recharge by harmful chemicals
groundwater protection	– exclusion of the input of harmful chemicals to sensible areas – no establishment of waste deposits and industrial areas
habitat function	– establishment of nature reserves – protection and development of valuable biotopes – creation of buffer zones and stripes – establishment of biotope networks – reduction of impacts by fertilizers, biocides, air pollution
potential for recreation	– preservation of scenery and landscape characteristics – enrichment of the agrarian landscape by many and diverse landscape elements – restoration of running waters – reduction of air and water pollution

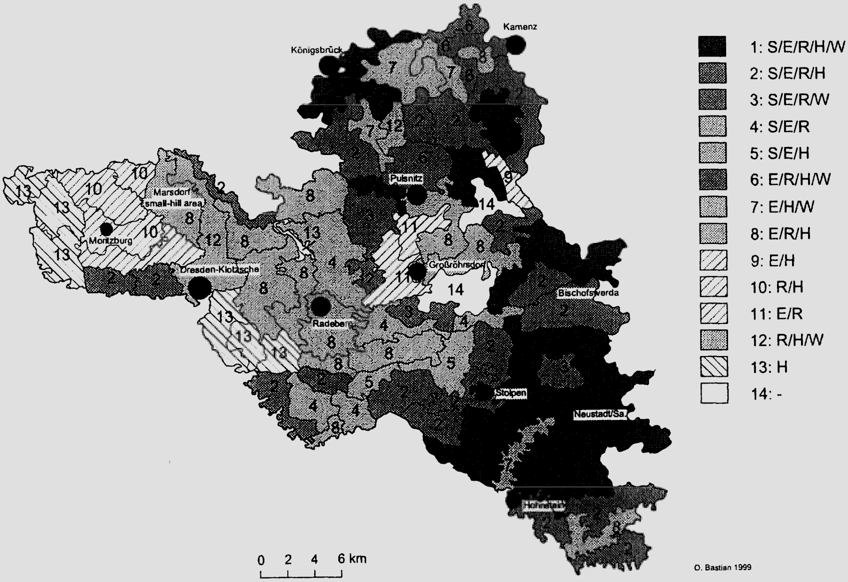
The integration is the crucial step to make several, partly incongruent, objectives consistent with each other. Such interrelations can be identified and visualized using an **ecological matrix** (Figure 7.2-6). For example, land abandonment is favorable for the control of soil erosion (s2,s3: +). Afforestation in sensitive areas (for groundwater protection) does not correspond with the goal of maintaining extensive land use in order to protect valuable meadow communities (w3,b2a: -). It is worth mentioning that in many cases interrelations in heterogeneous reference units (chorological dimension) are only of theoretical interest, since the phenomena are not always located on the same place within a reference unit. One example: there are conflicts between the demands to preserve productive soils for agriculture on the one hand, and the increase of numbers and sizes of valuable biotopes on the other hand. But in practice, appropriate sites for the development of valuable biotopes are mostly related to such places within a landscape unit where are less favorable conditions for the agriculture (poor, moist or dry soils, slopes, fragmented fields).

	soil			water				climate/ air			species and biotopes								scenery/ recreation		
goals	s1	s2	s3	w1	w2	w3	w4	c1	c2	c3	b1	b2a	b2b	b3a	b3b	ba4	ba5	b5	r1	r2	r3
s1		(-)	-	+	-	-	-	+	+	+	-	(-)	-	(-)	(-)	-	--	(-)	(-)	-	+
s2			+	0	+	+	+	(-)	(-)	0	+	+	+	+	+	+	--	+	+	+	0
s3				+	-	+	+	-	-	+	+	-?	+	+	+	?	--	-	0	+	+
w1					+	+	+	0	+?	+	+	+	0	(+)	+	+	+	+	+	(+)	+
w2						/	+	0	0	0	+	+	+	+	+	+	+	+	+	+	0
w3							+	-	-	+	+	-	(+)	+	+	?	+	+?	?	+	+
w4								(-)	(-)	0	+	+	+	+	+	+	+	+	(+)	+	0
c1									+	+	(-)	0	0	0	(-)	0	0	0	+	-	+
c2										+	-	+	(-)	0	-	?	0	0	+	-	+
c3											+	0	0	+	+	+	+	+	+	+	+
b1												0	+	+	+	+	+	+	(+)	+	+
b2a													+	+	(+)	+	+	+	+	+	+
b2b														+	+	?	+	+	?	+	+
b3a															+	+	+	+	+	+	+
b3b																+?	+	+	(+)	+	+
b4a																	+	+	+	+	+
b4b																		+	+	+	+
b5																			+	+	+
r1																				(+)	+
r2																					(+)
r3																					

Figure 7.2-6: Ecological matrix: objectives for landscape factors and functions - congruencies and conflicts (additional explanation in Bastian 1999c)

• positive interrealations (corespondence), - negative interrelations (conflicts), 0 indifferent, ? special check of single cases, / facts are mutually exclusive, () is valid for afforestation

In consequence of a high diversity of landscape characteristics in a reference unit (with regard to landscape functions, threats, risks, goals, measures), a **typification** is necessary (Figure 7.2-7). For example, within the reference units "type 1" the ensemble of all five goals (and related measures) are necessary: preservation of productive soils for the agriculture (S), measures against soil erosion (E), improving runoff regulation ®, avoiding impacts by wastes (H), maintenance of high groundwater recharge (W). In contrast to it, "type 10" demands only a better water retention capacity ®, and the protection against harmful substances (W). Naturally, the number of such types can be reduced with an increasing generalization of parameters and vice-versa.



S: Preservation of productive soils for the agriculture
E: Measures against erosion have priority
R: Improvement of runoff regulation (water retention capacity)
H: Avoidance of inputs of harmful substances / wastes --> esp. extensification of land use necessary
W: Maintenance of high rates of ground water recharge --> no large-scaled afforestation or surface sealing

Figure 7.2-7. Landscape ecological contributions to the elaboration of targets (Leitbilder) for landscapes in landscape units (microgeochores) of Western Lusatia (Saxony, Germany): complex soil and water (from Bastian 2000b)

The problem of optimizing and harmonizing different, even contradicting, targets, can be solved also with mathematical methods (see Chapter 5.4).

A **quantification of targets for nature conservation** was also attempted by Duhme et al. (1997) in a **case study in Bavaria** (Germany). Ecological land units and landscape structure units were defined and mapped to quantify the conservation targets for the areas with predominantly agricultural land use. The units are relatively homogeneous in relation to the dominant land uses and their physiognomic features. Land use and structural features were recorded for each unit including:

– cover of the different crops (e.g. hop, cereals, corn),

- cover of ecologically important sites, mapped in the Bavarian habitat survey, and
- cover of further small scale habitat structures (e.g. grassy field verges, small wastelands).

Spatial indices were then used to evaluate wildlife habitat potential of the different structure units (e.g. hedgerow density per ha agricultural land). In matching the structure units with topography, the average slope for each structure unit could be calculated (TIN-Cascading). The "Universal Soil Loss Equation" (USLE, see Chapter 5.2.2) was used to calculate the minimum density of contour parallel hedgerows required per landscape structure to keep soil erosion below a threshold value of 7t/ha*a. As a result of the investigation, some 1934 ha, that is 14% of the research area, were included in the nature reserve system. Of this area, 649ha can be developed within existing (commercial) forests, whereas 1,285ha of arable lands have to be afforested. Another 967ha (7% of the research area) will have to be converted to extensively managed grasslands for soil and groundwater protection. For the reduction of soil erosion as well as for the protection of field flora and fauna, additional areas are needed.

7.3 Landscape planning

7.3.1 Definition and tasks of landscape planning

A "continuing process that strives to make the best use for mankind of the limited area of the earth's surface while conserving its productivity and beauty", so reads the **definition** of landscape planning by the Landscape Planning Commission of IUCN (Takeuchi 1983). Bastian and Schreiber (1999) interpret landscape planning as a planning for the preservation and the development of landscapes as spatial patterns of ecosystems with the aim to keep the sustainable capacity of nature and to protect its scenic beauty.

Landscape planning deals with the landscape as a system of biotic, abiotic and anthropogenic factors. Against the background of sustainable land use development landscape planning emphasizes (following Mannsfeld 2000b)

- the protection of the typical variety of species and biocoenoses in every landscape,
- the preservation and the restoration of soils by the prevention of their degradation and by renaturation,
- the preservation and the restoration of water quality by the prevention of contamination and the redevelopment of rivers and lakes, and

- the protection of scenic features of landscapes respecting their recreational quality.

Sustainability (see Chapters 7.1.4 and 7.9.2) is defined in the Brundtland Report (WCED 1987) as "path of progresses which meets the needs and the aspirations of the present generation without compromising the ability of future generations to meet their own needs". This definition characterizes sustainability not only as a principle of environmental precaution, but also as a guideline for preservation and development of human welfare. That means, sustainability is a multidimensional concept with competing objectives (Schmid 1997). Therefore landscape planners are challenged to pay attention to the demands of environmental protection, especially to the preservation of nature, on the one hand, and to take into account the requirements of land use on the other hand. It is important for the planner to support ways of land use which are economical with their own resources.

Landscape planning may thus be considered as a special area of applied landscape ecology with specific methodological procedures, determined by the principles of sustainable land use and nature preservation. The **difference between landscape planning and landscape ecology** is focused on the fact that landscape planning acts within the scope of environmental law but landscape ecology has the freedom to act within academia. Hence, it would be desirable for landscape ecology to create ideas and landscape planning to realize these ideas.

7.3.2 Landscape planning and regional policy

Environmental law summarizes the laws dealing with environmental issues. It concerns the regulation of the human impact on the natural environment and the protection of all the parts of the environment itself, e.g. air, water, soil, wildlife. Therefore it encompasses many laws. Landscape planners in Europe have to respect the national regulations as well as the regulations of the European Community. National regulations in some countries (e.g. Germany, Austria, Switzerland) are, not only enforced by the parliament of the Federal Republic, they can be also enforced by the federal states. And these laws cover all aspects of environmental problems. Here the regulations for active and reactive landscape planning are fixed. Reactive landscape planning (see Chapter 7.4) is connected with environmental impact assessment.

In most European countries landscape planning is integrated in regional planning and sectoral planning for land using branches (Table 7.3-1). Following the Natural Conservation Act in Germany **landscape programs** point out the principles of landscape development in every federal state. Additionally **landscape skeleton plans** reflect the guidelines of landscape development within districts and **landscape plans** describe the local landscape development within communities. The Natural Conservation Act demands landscape plans, if they are necessary for reasons of natural preservation or landscape management.

Table 7.3-1: Instruments of landscape planning in Germany, Austria and Switzerland (according to Boesch 2000, Dollinger 2000)

	Germany			Austria		Switzerland	
		sectoral planning					
level of planning	regional planning	nature conservation, recreation	agriculture, forestry, water management	regional planning	sectoral planning	regional planning	sectoral planning
federation	regional policy program			conception of regional policy			factual plan inventory list
federal state/ canton	development program of the federal state	landscape program		provincial development program	sectoral development program	regional policy guiding plan	
region/ district	regional development plan	landscape skeleton plan	skeleton plans for forestry agriculture, water management	regional development plan		regional policy guiding regulation	
municipality	local development plan	landscape plan		local development conception	zoning plan for natural hazards, zoning plan for settlement building, zoning plan for land use transformation	regional policy regulation	zoning plan, landscape plan, ecological contract

Also other laws must be taken into consideration by active landscape planning in European countries, so in Germany the building code, which rules for settlement development and land use zoning, as well as the Water Balance Act and the Anti-Pollution Act.

The planners work within the framework of regulatory law. They have two important instruments to implement their concepts, zoning and siting:

Zoning is the main tool for the development of open space. As in the U.S., zoning defines the permitted uses of land in order to separate inappropriate land uses and to protect public interests. That includes the restriction of land use if it is necessary to protect landscapes from the degradation of their naturalness and the destruction of their cultural heritage. The consequence of zoning can be the assignment of plots of land in someone's disposal. In the U.S. land use zoning is only allowed in the case of regional or environmental nuisances. Otherwise land use zoning is considered as regulatory taking.**Siting** is the main tool for the management and the controlling of development projects. That concerns major projects like convention centers, shopping centers or large apartment complexes as well as minor projects in the open space like view points, trails and other recreational facilities, which establish opportunities for tourists to visit cultural or natural monuments and to enjoy wildlife without hampering the needs of preservation.

7.3.3 Scientific essentials in landscape planning

Landscape planning is aimed at the ecological aspects of regional policy. Landscape planning deals with landscape monitoring, landscape management and preservation of nature. To master these tasks planners must consider some scientific essentials of landscape ecology, e.g.

- the holistic approach of landscape ecology (see Chapter 1),
- the methodological trias of landscape analysis, landscape diagnosis and landscape prognosis (see Chapters 3.1, 3.2 and 4.3),
- the assessment of landscape functions, potentials and hazards (see Chapter 5.2), and
- the dimensional related landscape classification (see Chapter 2.2).

The **holistic approach** is the basic idea for planning in the meaning of sustainable landscape development. Contemporary ecological problems are often caused by unbalanced interferences in natural systems and unbalanced ecological answers, only with a special view on narrow compartments of natural systems, e.g. species preservation without considering the geosystem as a whole. Hence foresighted acting demands a holistic view. This view is primarily the basis of the guidelines and of the aims of environmental quality (see Chapter 7.2) which determine the line of landscape planning. Nevertheless it is a problem that guidelines and aims of environmental quality are often expressed in general phrases, and it is difficult to apply them in concrete situations.

Critics and skeptics say this approach is too woolly. However one can solve this problem not by renunciation of guidelines and aims of environmental quality, by working in segments. A general tool for the planners approach is necessary. But it is also necessary to complete general aims with the subordinated objectives of planning related to every concrete case. These objectives determine operational procedures, especially in data sampling and data evaluation. The evaluation of data must try to consider all aspects of landscape features. You cannot ignore side effects. Hence the holistic approach is the best way to get a real idea of landscape structures and landscape functions in the planning area.

7.3.4 Main steps of landscape planning

Landscape analysis, **landscape diagnosis** and **landscape prognosis** are the steps which determine the practical procedures of landscape planning. These three steps are a constituent part of the official achievement table for landscape planners and landscape architects in Germany (Figure 7.3-1).

The general conditions of the practical procedures of landscape analysis, landscape diagnosis and landscape prognosis in landscape planning are different from the conditions of landscape research. Landscape planning is limited in time and money. Compared to landscape researchers, landscape planners have less chance to work in the field. Landscape planners are usually restricted to available data.

Landscape mapping is mostly based on remote sensing data, especially orthophotos, and existing geographical information systems (see Chapters 6.1 to 6.3). Making demands for an additional terrain survey is successful when the available data are apparently insufficient. The application of landscape metrics (see Chapter 6.2.3) and the development of landscape models (see Chapter 6.4) is practicable if sufficient suitable data are available, and the metrics or the models can lead to new findings. Nowadays, there is increasing use of multivariate statistical approaches and modeling techniques with the increased technical advances and experience of planners. But it is still necessary to transform the metrics of patches or patterns in the landscape, and the results of modeling, into a language intelligible for every user.

The assessment of **landscape functions, potentials and hazards** in landscape planning must consider the mutual relations between the landscape features first. Against this background their functional importance is derived from the contribution of landscape patches and landscape patterns to the balance of matter and energy in nature. The planner must characterize the functional importance of landscape patches, e.g. vegetation units, soil units, lakes, river segments and meso-climatic areas, and their patterns verbally as well as by metric indications. This should be the framework to assess the **carrying capacity** of landscapes (see Chapter 5.1) and the evaluation of natural potentials and natural hazards.

Potentials and hazards characterize the socio-economic opportunities of land use, related to the natural constraints of landscapes and of the current levels of technology. If necessary, the disposition for the different kinds of land use can also be shown. Accordingly, it is useful to fix the hazards. In a synthesis of the results it is possible to draw conclusions about the carrying capacity of landscapes. It is important to understand that the methods of evaluation of functions, potentials, land use dispositions or hazards are very varied (see Chapters 5.2 and 5.3). Therefore, it is necessary to describe precisely any applied evaluation methods in landscape plans.

landscape inventory
(landscape analysis)

natural structures and functions | structures and functions of land use

- characteristic of natural compartments (relief, soils, water, climate/air, vegetation, animals)
- characteristic of land use (settlements, agriculture, forestry etc.)
- characteristics of mutual relations between natural equipment and land use
- characteristic of sensitive areas (nature reserves, recreation areas, cultural monuments areas of mineral or water resources, old neglected areas of waste deposits etc.)
- mapping of landscape units (biotopes, pedotopes, hydrotopes, climatopes or corresponding chores) as spatial patterns of ecosystems
- mapping of areas fixed by statut ory regulations and existing plans
- synthesis

landscape evaluation
(landscape diagnosis)

ecological functions | potentials and hazards

- evaluation of landscape units (biotopes, pedotopes, hydrotopes, climatopes or corresponding chores) as spatial patterns of ecosystems
- assessment of scenic beauty, cultural heritage, recreation areas
- synthesis

decision on landscape development
(landscape prognosis)

landscape monitoring | conservation of nature
landscape management | design of landscapes

- decision on guidelines and aims to keep the sustainable capacity of nature and to protect the scenic beauty of landscapes
- zoning and siting of planning units
- decision on steps of nature conservation (development of natural reserves etc., nature monuments, preserved parts of landscapes, protected biotopes, protected species)
- decision on steps of sustainable land use (recreation, agriculture, forestry, water management, settlement development etc.), combined with
  - preservation of scenic effects of landscapes and cultural heritage,
  - protection of mineral and water resources,
  - redevelopment of old neglected areas of waste deposits
- synthesis

Figure 7.3-1: Steps of landscape planning

Every option and every decision of landscape planners must be related to spatial units. By means of scale-related landscape classification the basic structure of functional landscape units can be described in a way which allows a comparison of the results of landscape inventory in different regions. Scale-related **landscape classification** in landscape planning distinguishes between topological and chorological scales. **Topological landscape units** (e.g. biotopes, pedotopes) are the spatial basic units of landscape plans. As a rule, biotopes and pedotopes are officially typified and classified so the planner can describe their substance and their structure on the basis of official type lists.

Chorological units, which consist of groups of topic units, are rarely typified. Such groups vary strongly, and the precondition of typification is a basic entity which is extensive enough for this step. Nevertheless in some Central European regions, e.g. Saxony in Germany (Mannsfeld and Richter 1995) and in the Salzburg country in Austria (Dollinger 1998) official lists of typified and classified landscape units exist (see Chapters 2.2 and 6.1). That makes the planners work easier and the characteristics of landscapes in the chorological level more comparable as in other cases, when landscapes only are described as individuals. But the planner must know: type-lists and the classifications are only fitted for regions and not overall applicable. Nevertheless types and classes are tools for an efficient computer-aided planning and are therefore indispensable.

As a rule, existing **nature reserves** (see Chapter 7.7) are untouchable for planners. Normally they are irrevocable planning categories, because they are defined by law and equivalent regulations. Revocations can be made only by legislative representations. Nevertheless landscape planners are authorized to express proposals to establish new nature reserves. In Germany the legislator distinguishes between natural reserves in a narrower sense (statutory natural reserves), landscape reserves, national parks, nature parks, nature monuments and preserved parts of landscapes. Very strict protective regulations are in force for statutory natural reserves. Within landscape reserves however, several kinds of land use are tolerated, if they not act contrary to the protective objectives. Nature parks are nature formed areas, which are particularly used for recreation. Hence, nature parks in Germany cannot be equated with wildlife parks.

7.3.5 Problems of implementation

Planning is a step into the future. But planning cannot be equated with the future reality. In Germany and other European countries the great number of laws and statutory regulations often causes long-winded planning processes. The planning process is occasionally confronted with "fait accompli". Therefore during the last years the legislators attempted to clear laws of regulatory ballast. Arrangement procedures between civil actors and official authorities like in the U.S. or Japan are taken into consideration. More and more planners prefer project- and management-related methods. These methods include a discursive project development, with contact with the people concerned (see Chapters 7.9.6 and 7.12). The activity of decision-makers like public authorities and private companies to test such an approach is, however, often limited. Hence in the last years, flexible planning methods are only punctually adopted by legislation.

A well-known example for project- and management-related approaches in Germany is the International Building Exhibition, Emscher Park, where architecture projects in a changing landscape have been presented since 1991. The remains of a mining industry, shut down during the last ten years, are transformed into park and housing areas, and completed with college buildings, museums of technology or technical monuments and towers overlooking the former mining areas. This was a successful demonstration of the opportunities involved in a project-related planning approach. The International Building Exhibition, Emscher Park, shows that only a settled plan is effective. Planners should be able to demonstrate their projects. Reality does not wait for planners' ideas.

7.4 Environmental Impact Assessment

7.4.1 Aims, principles and history

The assessment of the environmental impact examines the possible effect of a proposed action on

- the physical environment: relief, geology, soil, surface water, groundwater, climate, air,
- the biological environment: flora and fauna with specific consideration for rare or endangered species, and
- the human well-being: free from noise and air pollution.

Environmental Impact Assessment (EIA) comprises all the investigations which are necessary to protect human health and welfare, to preserve flora and fauna, soil, water and air from pollution and other harmful side effects of human activities, and to reduce or to eliminate existing environmental damage. **Three principles** must be considered in this procedure: the principle of precaution, the principle of causality and the principle of co-operation. Following the principle of **precaution,** the first aim of EIA is to avoid environmental damage before it arises: at the "beginning of the pipe" and not at the "end of the pipe". Following the principle of **causality** the second aim of EIA is to delineate the causes of existing environmental nuisance, to show ways to solve the connecting problems and to clear up the responsibility. Following the principle of **cooperation,** the third aim of EIA, is to include the people concerned by the proposed action in the decisions on the project (see Chapter 7.12). EIA is a central assignment of reactive landscape planning (see Chapter 7.3) in Europe.

The model for the enforcement of the EIA was given by the procedures defined in the U.S. environmental legislation (Wood 1995). Since the revised version of the U.S. Clean Air Act 1979 (Section 309) authorized the Environmental Protection Agency (EPA) to establish EIAs, environmentalists in Europe have been calling for similar statutory regulations. As a result of their demands, in 1985 a guideline of the Council of the European Community ordered the member states to adopt EIA into national law. This occurred step by step in the following years, e.g. in Germany 1990 and in Austria 1994. In Switzerland, not a member of the European Community, the regulations of EIA are integrated in the Environmental Protection Act which had already been passed by the parliament in 1983. A thorough overview of the EIA in different countries is given e.g. by Donelly et al. (1998), Gassner and Winkelbrandt (1997), Petts (1999), Ruge (1998) and Vanclay and Bronstein (1995). Recently EIA must be completed in the European countries by a spatial impact assessment for the areas of the European Ecological Network "Natura 2000".

7.4.2 Procedures of EIA

In legal terms EIA is classified as a dependant procedure. That means: dependent of a legal administrative process. The **projects requiring EIA** are listed, e.g. in the annex of the Environmental Impact Assessment Act of the Federal Republic of Germany:

- construction and operation of power stations, heating stations, refineries, chemical works, glassworks, works for explosives, shipyards, steelworks, foundries, chicken farms, mast plants for swine or cattle, incineration plants, nuclear plants, waste disposal plants, mines (Figure 7.4-1), and
- construction or modification of highways, waterways (Figure 7.4-2), railway lines, tramlines, test tracks for rail vehicles or motor vehicles, race tracks, motordromes, airports, pipelines, power lines, recreation centers, leisure centers.

The investor proposing an action or project has to submit an environmental impact study to the official authorities. As a rule, EIA must be done with public participation (Table 7.4-1).

Figure 7.4-1: Quarries cause irreversible landscape alterations and damages: A granite quarry in the Upper Lusatian hilly country (Saxony, Germany) (Photo: O. Bastian 2000)

Environmental protective goods, in the legal sense, are men, animals and plants, soil, water, air, climate and landscape, including the interaction between these protective goods, cultural goods (monuments of architecture or archaeological monuments), technical goods and mining resources.

Environmental protective goods are examined twice in Germany: first as a problem of regional policy, second within the approval proceeding. Principally the German authority which is responsible for the approval proceeding is not bound by the previous decision of the authority competent for the examination of regional policy aspects. In the other European countries only one step of EIA is necessary. This prevents a contradiction between the decision of the regional policy authorities and the decision of the project approval authorities. In Germany, a one step assessment might be imaginable under the competence of regional policy authorities, when the regulations for EIA in the frame of regional planning are enacted as the Council of the European Commission demands.Usually private planning consultants or planning companies work out the environmental impact studies (EIS). Every planner entrusted with this job must respect many statutory regulations. Not only must the Environmental Impact Assessment Act be considered, but also the statutory regulations for regional policy and nature conservation must be taken into account. Moreover, the anti-pollution act and the acts of settlement development, soil and mineral resources protection, mining, water management, agriculture, forestry or home land protection (in Switzerland) are relevant to the examination of environmental problems. In all cases the legislator demands, that the EIS explores all the environmental impacts of the proposed action and all the interrelations between these impacts. The results of the EIS must be submitted to the authorities in time for the decision on the proposed action. The presentation of the results should be understandable for a general public (Gassner and Winkelbrandt 1990).

Figure 7.4-2: River regulation and the reconstruction of hydroelectric power stations require an Environmental Impact Assessment: The Rhine near Marckolsheim (German-French border)(Photo: O. Bastian 2000)

Table 7.4-1: The German approval procedure of proposed actions which must be examined by an Environmental Impact Assessment

N°	step of approval procedure	persons or bodies concerned
1	submission of the project plan, connected with the environmental impact study and the attendant plan of landscape management. Supplementary: plan of reorganization of traffic routes, reshaping the farmland plots, afforestation	investor and planning offices
2	comments	public authorities and environm. organizations (NGOs)
3	first improvement of the planning documents	investor and planning offices
4	public display of the planning documents (1 month)	communities and NGOs
5	opportunity for objections to the planning documents by letter (deadline 2 weeks after the end of the public lay out)	communities and NGOs
6	public discussion	public authorities, NGOs and communities
7	statement on the results of the public discussion	public authorities
8	second improvement of the planning documents	investor and planning offices
9	decision of approval	public authorities
10	public display of the approved version of the planning documents	public authorities

N°	step of approval procedure	persons or bodies concerned
11	opportunity for appeal against the approval (deadline 2 weeks after the end of the public lay out)	communities and environmental unions
12	order of the court (if the approval is confirmed, it becomes uncontestable 1 month after the last court order)	courts of justice
13	begin of the construction work	investor, builders and contractors

The routines for the development of **environmental impact studies** (EIS) are similar in most European countries. The official achievement table for landscape planners and landscape architects in Germany provides five steps of work:

- project information,
- landscape inventory,
- landscape evaluation,
- conflict analysis: determination of considerable impacts, and
- development of concepts for alternatives.

The EIS must consist of text and maps, describing every step of work.

7.4.3 Management of interference in nature and landscape

If the EISbelongs to the approval proceeding, in Germany an attendant plan of landscape management is necessary. Here the Federal Nature Conversation Act has drawn up rules for the management of interference in nature and landscapes, before the Environmental Impact Assessment Act passed through parliament. An **interference** in nature and landscapes is defined by law as the impact on the shape or the utilization of land plots in a way which hampers the natural balance of energy and matter or disfigures the scenic features of the landscape. Everyone who wants to plan a project must avoid foreseeable interference of nature and landscapes. Unavoidable interference is to compensated by steps of nature conservation or landscape management. The compensation must be carried out in a functional and chronological connection with the interference (LANA 1996). The aim is a spatial connection.

According to the German Nature Conservation Act, the course of the development of the **attendant plan of landscape management** must be examined for flora and fauna, soil, water, air, climate and scenic features of the landscape (the latter in connection with the recreational facilities).

Unlike the EIS only the natural **protective goods** must be considered. The protective good "humans" and the cultural goods, the technical goods and the mining resources are not taken into account. But the steps of elaboration the EIS, which provides the official achievement table for landscape planners and landscape architects, are partly comparable with the **steps of elaboration** the attendant plan of landscape management:

- project information,
- landscape inventory,
- landscape evaluation,
- conflict analysis: description and explanation of considerable and sustainable interference,
- development of concepts for the reduction or compensation of interference,
- development of the balance sheet (synopsis of impact effects versus compensation steps), and
- estimate of compensation expenditures.

Analogous to the environmental impact study the attendant plan of landscape management must be presented with text and maps.

The development of the EIS and the attendant plan of landscape management is connected with a lot of **problems of applied landscape ecology**. Above all, three should be named:

- the allocation of impacts caused by the proposed action,
- the determination of considerable and sustainable interference, and
- the siting and the timing of compensation activities.

The **spatial effects** caused by the proposed action were usually derived from so-called **impact-impairment-chains** which characterize the effects of interference on landscape qualities. The field of impact-impairment-chains must be determined as exactly as possible. Most often, the planner cannot realize a test in the terrain with such a narrow analytical focus. Usually the planner must look for comparable studies or consult his own experiences. This is not always sufficient. Hence the results of the allocation of impacts are sometimes burden with a rest of uncertainty.

Irrespective of this problem a synopsis of project-related impacts is necessary. This will be achieved by means of a GIS (see Chapter 6.2). A detailed database is developed which comprises all the data for the description of landscape features ont the one hand and the characteristic of the impacts on the other. In the GIS these data must be linked with spatial reference areas. The objective is to obtain the basic information about the dimension of interference and the extent of activities for compensation. Two methods are used: the first way is to produce an overlay of several topological or chorological units. The resulting layer shows the smallest common geometry of these topological units. The landscapes are atomized into many basic units as a result of the fragmentation of the analytical horizons. This usually exceeds the limits of practicability. Planners prefer the second way. Here **biotopes** are used as standardized spatial reference areas, because the less quantity of these basic units is far better manageable as the major quantity of the smallest common geometries. Furthermore the assessment of biotopes can be realized in a verifiable way. Data sources from remote sensing or GIS are available in many regions. Field surveys, if required, can be realized routinely and biotope typologies and classifications of biotopes exist in many places.

Only considerable and sustainably stressed areas must be taken into account in the frame of EIA and the attendant plan of landscape management. Hence the threshold of considerable and sustainable interference is to define. This can be achieved by **ecological hazard analysis**. The term describes a group of methods, the aim of which is to characterize the relation between human activities and the change of landscapes concerned. Following the basic idea of ecological hazard analysis, the determination of considerable impacts is derived from the intensity of impact on the one hand and of the functional importance of the spatial reference areas (e.g. biotopes) in the field of the impact on the other.

Functional importance means the importance of the spatial reference areas for the natural balance of energy and matter, assessed within the scope of landscape evaluation. As a rule functional important areas are also sensitive to interference. Functional importance and **sensitivity** (see Chapter 5.1.2) are described verbally as well as scaled in several (mostly five) steps. All the nature reserves are high rated, areas of waste deposits for instance are low rated. Intensively used grassland, etc., is medium rated. The intensity of impacts is characterized by the extent of interference, related to one spatial reference area, and graduated due the effects on their structure and function in a scope between negligible and total loss. Impacts on medium to high rated reference areas exceed the threshold of considerable interference as well as noticeable impacts everywhere (Figure 7.4-3).

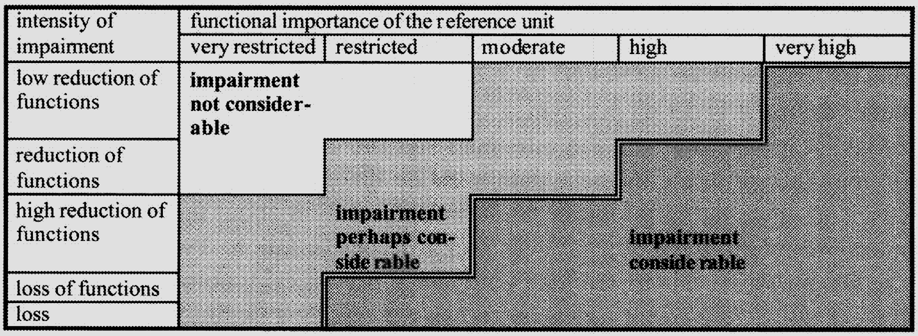


Figure 7.4-3: Scaled assessment of considerable impacts

Sustainable interference is determined by the period of time, which should be necessary for the regeneration of the impacted ecosystems and areas. Regeneration means the re-establishment of landscape structures or functions comparable to the structures or functions existing before the project started (LANA 1996, see Chapter 7.11.2 and Table 5.2-5). It is very difficult to determine regeneration periods in a generalized way and therefore the planner is sometimes confronted with several options. One must then decide on the basis of experience. If necessary, the planner can describe where the scientific basic is insufficient, otherwise one is bound by law to characterize clearly the results of impact assessment. This is carried out in text and maps. The maps show the spatial distribution of all the ecological hazards concerned to the proposed action and point out the areas of considerable and/or sustainable interference.

Compensation activities are focused on the development of landscape structures and functions comparable to the ecological structures and functions in the areas of considerable and/or sustainable interference.

The objectives, the quantity and the way of compensation steps must be derived from nature and the extent of the impacts, which are likely to impinge on landscape features in relation to the guidelines of landscape management and landscape development in the study area. The legislator demands that all the compensation steps can be proved in the sheet. Every step is to describe in detail and to relate to a concrete impact (Table 7.4-2).

Table 7.4-2: Extract from a balance sheet

	considerable or sustainable impact						
	conflict area				impairment		
N°	type of biotope	functional importance	extent	state of protection	loss	loss of functions	reduction of functions
1	coniferous forest	moderate	10 ha		+		
2	row of trees	high	1 km				+
3	wet grassland	very high	5 ha	protected biotope		+	

versus

	compensation step							
	compensation area				compensation objectives			
N°	existent type of biotope	functional importance	extent	availability of land	target type of biotope	functional importance	state of protection	period of development
1	fallow farmland	low	20 ha	common pool	mixed forest	high		30 years
2	farmland	low	1 km	private property	double row of trees (avenue)	very high	protected biotope	30 years
3	fallow grassland	moderate	10 ha	private property	wet grassland	very high	protected biotope	10-30 years

So the planner sometimes runs the risk of developing a simple input-output balance, where the project impacts are compensated by isolated activities of landscape management. Therefore it is useful to work out a **coherent compensation concept**. This concept guarantees coherent landscape management in the compensation area, because every concrete step of compensation must be integrated in a general line of action.

Compensation can sometimes be, strictly speaking, a kind of interference. Otherwise, some impacts, e.g. attractive new buildings like bridges or towers, can occasionally enhance the scenic beauty of landscapes. The environmental law does not consider such aspects. But it is worthwhile to have these points of view at the back of the mind. So the planner is able to see harmful side effects of compensation steps and to look for the balance of impact effects in an unbiased way. Championing a holistic approach to the evaluation of impacts and to the methods of compensation excludes a simple swap with nature.

7.5 Farming and the landscape: Structures of organic and conventional farms

7.5.1 Agriculture and the landscape

The relationship between agriculture and the landscape is a mutual one and has a long tradition. European landscapes have been used for agricultural purposes for more than 6,000 years. Farmers' actions have influenced and shaped the landscape while the landscape has influenced farming practices and attitudes of farmers (B. Tress 2000). Today, large parts of the landscape are still used for agriculture. In Europe, on average 40% of the territories are dedicated to agricultural usage (European Commission 2000). Thus, it is fitting that agricultural landscapes should be an important issue within landscape ecology.

Many landscape ecology studies on agricultural landscapes focus on the landscape as a (threatened) habitat for animal and plant species (Farina 1997, Freemark 1995), biodiversity and heterogeneity (Duelli et al. 1999, Lockwood 1999, Norderhaug et al. 2000, see Chapter 2.3.4), on fragmentation and isolation (Fitzgibbon 1997, Grashof-Bokdam 1997, see Chapters 2.3.7 and 2.8.2) or the development of small biotopes in agricultural landscapes (Agger and Brandt 1991, Baudry et al. 2000, Holland and Fahrig 2000).

Some of these studies already show a conflict of interests between agriculture and nature conservation and societal demands for a sound environment. For more than two decades, the conventional agricultural method has been in crisis and an ongoing subject of public debate. News about its negative environmental impact and food scandals are coming up continuously and have led to criticism of conventional agriculture by the public and landscape ecologists alike.

7.5.2 The appearance of organic agriculture

Parallel to this debate and partly as a direct reaction to conventional agriculture, alternatives have been developed. Organic agriculture became standardized and appreciated as a low-input system with distinctive advantages for the environment. Organic agriculture originated in the ideas of the Steiner school of the early 20th century. This grassroots movement was belittled by the establishment in the 1970s. Popularization of organic agriculture was not the result of scientific and technological inventions, but rather through private initiatives of farmers and consumers (Hamm and Michelsen 1996).

Within the EU, it achieved significant growth within the last decade, now representing 2.6% of the total agricultural area, equal to 3,345,938ha, and practised on 1.75% of all European farms (SÖL 2001, Figure 7.5-1). Yet these figures hide large differences between countries. Austria is at the top of the list with 8.43% of its agricultural area managed organically while Ireland is at the bottom with 0.75%. In some countries, organic agriculture has become part of the official agricultural policy and government legislation is passed to foster its development. Big supermarket chains have discovered its economic potential and have launched special marketing strategies for organic food. The organic food industry seems to have all the characteristics necessary to become a cornerstone of sustainable agriculture: it is environmentally sound, economically successful, and socially benign.

7.5.3 Landscape ecology and organic agriculture

Organic agriculture has piqued the interest of landscape ecology and the number of related studies undertaken has increased within the last few years. Many of the studies focus on the environmental effects of organic agriculture (Haas et al. 2001, Hansen et al. 2001), not on its relationship to the landscape as a whole. They discuss the different effects of organic and conventional agriculture on soils (Vogtmann and Ries 1998), water (Brandhuber and Hege 1992), climate (Köpke 1994), wild herbaceous plants in fields and grazing areas (Elsen 2000), and diversity of the fauna in agricultural landscapes (Christensen and Mather 1997, Odderskær et al. 1997). One exception, however, is the EU's Concerted Action group, which is studying "Landscape and nature production capacity of organic and sustainable types of agriculture" (Mansvelt and Lubbe 1999). They tested methods and tools for evaluating landscape quality on a small number of organic farms.

But there is a lack of studies that deal with the effects of organic agriculture at the scale of the landscape, studies that would involve a larger number of farms and thus would allow for broader conclusions. How would landscapes appear if there were a considerable percentage of organic farms? What would be the differences in landscape structure? There are other questions to be answered: Do organic farms have larger or smaller field patches, a higher diversity in crops? Is there a difference in fallow areas on organic versus conventional farms? Are there more or fewer hedgerows, ponds and other structuring elements on organic than on conventional farms? Are organic farmers more active then their conventional colleagues in establishing new biotopes? All these issues are of enormous significance considering the EU-wide growth rates of organic agriculture.

Figure 7.5-1: In the Scandinavian countries, the share of extensive and organic farms is growing steadily: Dry meadows and Juniperus shrubs near Volentuna (Central Sweden) (Photo: O. Bastian 2001)

A study was conducted in Denmark that aimed at comparing the landscape structures of organic and conventional farm estates (B.Tress 2000). It sheds a more detailed and differentiated light on the differences between these two types of agriculture. The study surveyed organic and conventional farmers in the counties of Ribe and Vestsjælland. Questionnaires were distributed to the farmers by mail. In all, 514 questionnaires were analyzed, comprising 369 from conventional farmers and 145 from organic farmers.

7.5.4 Organic agriculture in Denmark – a defined mode of production

Recognizing that there may be uncertainty as to the definition of organic agriculture, it is referred to in this context as the official production method defined in the national regulations for organic agriculture in Denmark (MFLF 1994), which are largely identical to the international rules of the International Federation of Organic Agricultural Movement (IFOAM 1997).

In order to get financial subsidies from official programs, organic farms must satisfy Danish **national regulations**, as follows: they may not use chemical fertilizers and pesticides. They have to maintain or improve fertility and biological activity of soils by crop rotations that include pulse crops or green manure, by ploughing under organic matter, and by livestock manure. Animals have to be kept in a manner appropriate to their physiological and behavioral needs. Stables have to offer enough space for movement, enough litter, fresh air and daylight, and animals may not be fixed. In summer season (at least 150 day/year) all animals must have access to pastures. The Danish national regulations do not contain any declarations concerning landscape management on organic farms.

The term "organic agriculture" includes the two most important branches of organic agriculture, biodynamic and organic-biological farming. The main difference between them is the anthroposophical philosophy upon which biodynamic agriculture is based and the lack of such a philosophical superstructure for organic-biological agriculture. When the term "organic agriculture" is used in this chapter, both types are meant.

The number of Danish organic farms has risen continuously over the past few years. At the beginning of the 1980s there were about 40 to 80 farms, mostly biodynamic ones. In 2001, there were about 3,750 organic farms in Denmark, which means that approximately 6.5% of all Danish farms and 6.6% of the total agricultural area are managed organically (Danmarks Statistik 2000).

7.5.5 Landscape structures: Production- and non-production areas

According to Forman and Godron (1986), landscape structure is composed of "patches", "corridors" and a "matrix" (see Chapter 2.3). This approach has a strong bio-ecological orientation. Zonneveld (1995) refers to a "landscape pattern", composed of "line-elements", "dot-elements", and a "matrix", which indicates a more neutral perspective. But neither framework was regarded as entirely suitable for this study.

Landscape is the concrete nexus of nature and culture (Tress and Tress 2001a,b). Agricultural landscapes are the result of a co-evolutionary process between humans and nature. Farmers' perceptions of "good farming practice" change with a conversion to organic farming (B. Tress 2000). And changed farming practice results in a changed farming structure. The structure of a complex system such as the landscape is about more than its physical appearance; it represents the organization of the system as a whole (Maturana and Varela 1987). One could even perceive landscape structure as the "physical embodiment of its pattern of organization" (Capra 1996). Thus, the differences in landscape structure have to be seen in relation to different farming systems.

From an ecological perspective, it is often valuable to have high diversity (se Chapters 2.3 and 5.1), and a high percentage of areas "closer to nature", where human impact is low and nature is able to develop freely. This assumption can imply the lofty attitude that agricultural changes degrade and damage the landscape's "natural" state, the way it is "supposed" to be (Cronon 1995). From an economic perspective, the goal is effectiveness, that is to say, high economic output for those exploiting landscape resources. Here, landscape structure is ordered in such a way as to maximize production. A cultural or social perspective may pay attention to the signals that structures send to other people. "People make landscapes in order to what they believe their neighbors will think or cautious assessments of market expectations" (Nassauer 1995). Thus, cultural conventions and customs directly affect what people notice about landscapes. Structural elements, such as hedgerows may not only be used to mark property boundaries, but may also be neatly trimmed in order to mark the good "care-taker". A historic perspective may focus on remnants from earlier periods like burial hills or stone walls and desire their conservation as part of the nation's cultural heritage (see Chapter 7.8). An aesthetic perspective may prefer richly structured landscapes to monotonous ones, and vertical landscape elements may be perceived different than horizontal ones. None of these perspectives exists in isolation. Instead, people always hold a mixture of attitudes toward landscape structures. But it is useful to stress that there are differences in the evaluation of landscape structure from a farmer's and from an ecologist's point of view and that these differences in attitude make it necessary to acknowledge that one's own perspective is only one among others (see Chapter 7.2).

Given the study's aims (B. Tress 2000), landscape structures on organic and conventional farms were the focal point. Data were gathered on the basis of the single farm estate, the total area property of a farm (including rented areas, excluding areas rented out). Thus it was most suitable to distinguish between **production and non-production areas** of farms (see Figure 7.5-2).

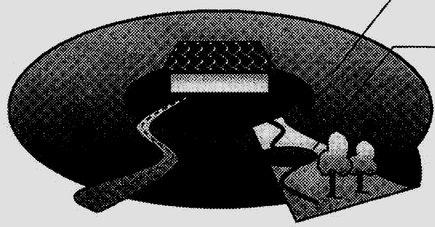


Figure 7.5-2: Production and non-production areas of farms

The total area of a farm includes all areas possessed by the farm owner, including rented areas. Agricultural areas comprise all areas used for production, including fallow areas and permanent grazing areas. Under non-production areas fall all other areas of a farm, excluding built-up areas. Non-production areas are all line and patch elements in the landscape such as road verges, field divides, hedgerows, stonewalls, ditches, dikes, tree rows, water draws, ponds, bogs, pits, burial hills, shrubs, solitary trees, groups of trees, plantations, ruderal areas. These elements are called **small biotopes** when an ecological function predominates or considered cultural landscape elements when their historic, aesthetic or cultural function predominates. Production- and non-production areas of a farm form the landscape structure.

7.5.6 Production areas on organic and conventional farms

The **sizes of individual field plots** and the way these plots are used have a determining influence on landscape structure. Enlargement of production areas often causes a reduction in non-production areas. When two fields become one, the field divide in between them is removed. Smaller field plots result in a higher percentage of edge areas while the total area remains unchanged. No less important for landscape structure is the **actual land use** of the field plots. It is a significant difference if only one field crop is grown on all plots or if there is high variability.

Crop rotation is an expression of landscape change. While the number and types of land use determine the variability of landscape structure on farms in one season, crop rotation can be said to determine the variability of landscape structure over several seasons. When farmers work with fixed crop rotations, land use on the different plots shifts each year, resulting in a more differentiated landscape structure. Both parameters are, however, closely linked to each other. An absence of fixed crop rotation on a farm often correlates with limited types of crops, evidenced by a monotonous landscape structure. Additionally, the number of seasons per rotation is relevant because this is connected to the number of plant varieties that are involved in one rotation.

Fallow areas on farms as well as permanent grassland could be counted as production areas as well as non-production areas, depending on the way they are used and treated. They may remain fallow for a period of 25 years (permanent fallow areas) and develop special vegetation, especially when they are not fertilized, but human influence is still felt: upcoming shrub and tree vegetation are usually removed. But there may also be fallow areas that, although rotation left unseeded in one season, are treated with fertilizers and pesticides just like other fields in rotation (rotating fallow areas). Permanent fallow areas influence landscape structure in that they are areas that develop more freely than others in the agricultural landscape, a fact that is valuable from an ecological point of view. Their aesthetic value may be controversial, as they do not appear as orderly and neat as other fields.

Permanent grassland areas are farming areas which are not periodically ploughed under and seeded afresh. They can be used either as pasture or meadow or as both simultaneously and development of special vegetation is characteristic for them. Permanent pastures and meadows are typical of the coinfluence of humans and nature in the landscape system.

Table 7.5-1: Comparison of parameters with relevance for landscape structure on production areas of organic and conventional farms

	organic farms	conventional farms
a) agricultural land use		
average agricultural area	45.2ha	38.9ha
average plot size	3.2ha	3.9ha
average number of land use types	3.0 types	2.8 types
dominant land use type (% of agricultural area)	grass/green forage 59.0%	grains 52.4%
b) crop rotation		
prevalence of fixed rotation (% of all farms)	70.1%	51.3%
duration of one rotation	5 years	4 years
number of plant varieties within one rotation	3.1 sorts	2.9 sorts
c) fallow areas		
prevalence of fallow areas (% of all farms)	38.2%	47.4%
percentage of fallow areas (% of agricultural area)	8.0%	10.0%
permanent fallow areas (% of all fallow areas)	47.0%	68.0%
d) permanent grasslands		
prevalence (% of all farms)	73.0%	57.0%
percentage (% of agricultural area)	27.0%	27.0%

The **study's results** are summarized in Table 7.5-1. The organic farms investigated were larger than the conventional farms and had smaller field plots. Landscapes on organic farms have a slightly more differentiated land use – within one season as well as within crop rotation. The dominant types of land use are rather different. While almost $^2/_3$ of the farming areas of organic farms are planted with grass and green forage, conventional farms devote more than half of their agricultural areas to grains. Organic farms have a distinctively lower percentage of fallow areas, including permanent fallow areas. By contrast, a very high percentage of organically managed farm areas was used for permanent grassland. Thus, differences in landscape structures on organic and conventional farms result in some rather distinctive changes (e.g. the differences in dominant type of land use, fallow areas and permanent grassland) and a wider range of small changes. But small changes can have rather large effects when related to the landscape as a whole and over the long term.

7.5.7 Non-production areas on organic and conventional farms

The **percentage of non-production areas** was first compared to total agricultural area (Table 7.5-2). Non-production areas comprise for instance, biotope, forest, bog, or water areas. The study surveyed only the total size of non-production areas not their spatial distribution or connection.

Table 7.5-2: Comparison of non-production areas of organic and conventional farms

	organic farms (average)	conventional farms (average)
a) non-production areas		
percentage (% of total farm area)	7.2%	6.5%
b) hedgerows		
total length (average length per farm)	1895.3m	1404.6m
density (length in relation to farming area)	54.8m/ha	45.7m/ha
c) establishment of new biotopes (since 1990)		
farms with new biotopes (% of all farms)	57.3%	47.7%
length of line biotopes	825.0m	465.6m
size of patch biotopes	3423.0m^2	3644.1m^2
d) Types of new established biotopes (since 1990)		
farms with new hedgerows (% of all farms)	78.6%	61.4%
farms with new plantings (% of all farms)	32.1%	38.6%
farms with new ponds (% of all farms)	14.3%	9.1%
farms with new other biotopes (% of all farms)	1.8%	2.3%

Prevalence and shape of **hedgerows** are closely related to agricultural usage of the landscape. In spite of the presence of bogs or small lakes, hedgerows are usually human-made. This means that they come into existence only when there is a demand for cattle fencing, property markers or shelter belts, to name just three examples. But hedgerows are not only important for individual farmers, but also for other stakeholders in the countryside. To compare farmers' activity in **establishing new biotopes/landscape elements**, the study focused on conventional farmers who had not started their farm before 1990 (95 in number) and organic farmers who had not managed their farm organically since1990 (103 in number). This guaranteed that both groups were treated equally in regard of the subject under investigation. The category "farms with newly established biotopes" indicates the number of farmers who had actually established new biotopes since 1990. As there was not asked after removal of biotopes, results have to be interpreted as gross increase.

The study looked at preferences of farmers for certain **types of newly established biotopes/landscape elements**.

The organic farms investigated had a slightly higher percentage of non-production areas, thus a plus in areas that are not intensively used. The total length of hedgerows was distinctly higher on organic than on conventional farms, as was hedgerow density. Organic farmers were also more actively considering the establishment of new biotopes/landscape elements on their farms. The line biotopes established on organic farms were on average distinctly longer than those on conventional farms, whereas patch biotopes were slightly larger on conventional farms. Almost all newly established biotopes/landscape elements fall into the three categories of hedgerows, plantings or ponds. Both organic and conventional farmers most frequently introduced hedgerows on their areas. Thus landscapes on organic farms are not only characterized by smaller field plots, but also by more biotopes of smaller size. All in all, landscapes of organic farms have smaller patches, a more differentiated land use, and are more richly interspersed with landscape elements, especially hedgerows. However, newly established landscape elements are confined to a few types only. Variation within a type, e.g. hedgerows, will have increasing importance in organic farming landscapes.

7.5.8 Discussion and conclusion

As mentioned above, landscape structure and agricultural practice are intrinsically linked to each other. The very high percentage of grass and green forage on organic farms can partially be explained by the fact that there is a high percentage of cattle farms among organic farms in Denmark. Other explanations are that the numbers of animals that may be kept on organic farms is tied to the agricultural area and that the amount of forage that may be bought from other farms is limited. Also, animals must have access to pastures in accordance with organic rules. Grain production is more difficult to realize in an organic way and thus there are fewer farms that specialize in this kind of production. These farms must work with crop rotation systems in order to maintain soil fertility. Thus a season with grains grown on a field plot will usually be followed by one or two seasons with plants capable of nitrogen fixation, i.e. leguminous plants, on the same plot. All these factors result in a high percentage of areas with grass and green forage/manure.

Because organic farming is low-input, low intensity-agriculture, it is rather area intensive. Area-bound stocking rates and rotation systems are area consuming. This may also explain the low percentage of permanent fallow areas on organic farms. Excluding fallow areas in rotation (e.g. those with leguminous plants), organic farmers simply do not have extra land that could be set aside permanently. The high percentage of permanent fallow areas on conventional farms should be seen in the light of the current EU subsidies for non-food production. The higher hedgerow density and the slightly higher activity to establish new biotopes on organic farms can probably be explained by the fact that organic farmers are encouraged to use biotopes, especially hedgerows, as tools for pest management. The smaller field plots and the higher percentage of farms that have a fixed crop rotation system may be advantageous from an ecological point of view. Higher percentages of permanent grassland and non-production areas may be evaluated positively, whereas the low percentage of permanent fallow areas can be seen as a disadvantage. From an aesthetic and cultural point of view, permanent fallow areas, to take one example, may have an untidy appearance and signal a lack of care and cultivation.

Some of the differences in landscape structures on organic and conventional farms demonstrated in this study could be explained directly by the change in farming practice, others may depend more on farmers' attitudes and thus be indirectly linked to farming practice. The illustrated differences are characteristic for the two Danish regions where the study was undertaken, but might be different in other European regions. Further studies are necessary. Comparative studies from other regions could show the degree to which the differences presented here are related to regional specifities and the degree to which they are typical of organic agriculture itself. There is a need for further studies that illuminate the relationship between farmers' attitudes, their farming practices and landscape structures. Such a study would be especially fruitful for non-production areas where farmers act more or less voluntarily.

More knowledge of the different landscape structures on organic and conventional farms may also help to adjust expectations of organic agriculture. And it is essential as a basis for decision-makers who are modifying existing or designing new subsidy principles for organic as well as for conventional agriculture. Here landscape ecology can certainly show itself to be an applied science.

7.6 Tourism and the landscape: A mutual relationship

7.6.1 Introduction

Tourism is shaping the landscape. Landscapes are inspiring tourism. Both statements characterize for the relationship between tourism and the landscape, but while the former is frequently considered in landscape and environmental research, the latter circumstance is often neglected in such research. Many studies focus, therefore, on tourism's substantial impact on the environment (Pignatti 1993, Schmitt 1994, Sun and Walsh 1998). By contrast, perception- and socio-economic-oriented studies (O'Hare 1997, Jenkins 1999, Pritchard and Morgan 2000) consider tourism as a phenomenon related to certain experiences and places. Very seldom are both kinds of studies combined, a legitimate but also reductionistic approach for these fields. Landscape is either understood as the physical environment that is impacted by tourist activity or as the construct that attracts tourists. In each case, landscape is investigated from a single point of view, be it natural or cultural, but not holistically, as is advocated here.

The landscape is a complex, dynamic system, made up of the subsystems geosphere, biosphere and noosphere, which are interrelated. People are part of the landscape by means of their actions and thoughts. Landscape also becomes part of people (Tress and Tress 2001a,b). To understand landscape in this way requires a different approach to landscape ecology studies in the field of tourism, one that transcends assessments of environmental impact. Of course, it is a main objective of landscape ecology to contribute to planning and management strategies that prevent tourism's potentially negative environmental implications. But such assistance alone will not solve the problem: researchers must consider the interdependence of tourism and landscapes, which are multifaceted and complex.

This chapter contains an example of a landscape ecological study in the field of tourism that integrates both sides of the tourism-landscape relationship. First, the changing tourism-landscape relationship will be contextualized with a synopsis of the development of modern tourism and its meaning in contemporary societies. Next, second-home tourism, which aptly illustrates the relationship between tourism and landscape, will be assessed as it relates to Denmark (G. Tress 2000).

7.6.2 The landscape-tourism cycle

For landscape ecology research to contribute to planning and management of tourist sites, researchers must recognize interrelations between tourism and landscape. Tourism and landscapes are shaping and influencing in what is called here the landscape-tourism cycle (see Figure 7.6-1). The relationship between tourism and landscape is systemic. When changing elements or conditions change within the system, all subsystems and other elements are altered.

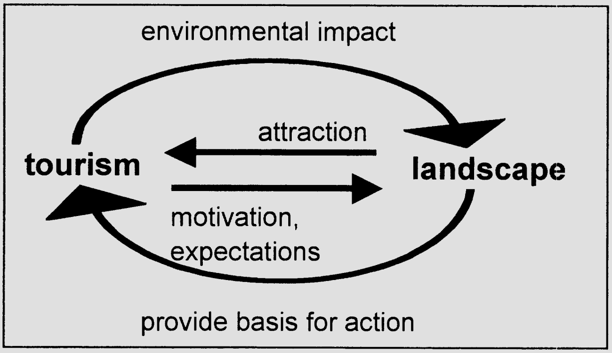


Figure 7.6-1: The landscape-tourism cycle

Tourism involves different actors: the tourists themselves, but also local communities, tour operators, and others employed in the industry. Tourists are most important agents in landscape-tourism interaction, visualized in the landscape-tourism cycle, but others inside and outside the industry exchange matter, energy and information in this open system.

A landscape has different functions and meanings for contemporary tourism: it is a habitat and a place to live; an area of production; a place for recreation; a place for experience, emotion and perception; and a place for culture and settlements. Many of these functions are closely interwoven with the physical dimension of the landscape, the environment.

Following the cycle, tourist activity is based on certain tourists' motivations and expectations. Landscapes attract tourists and influence tourist activity that on the one hand impacts the landscape. On the other hand, tourist activity could not be realized without the landscape providing the basis for it.

7.6.3 The development of tourism

Tourism is related to mobility and leisure. In classical times, **leisure**, called "otium", was reserved for the upper classes, whereas others were restricted to "negotium", daily work. First the efforts of the working class in the late 19th century brought up leisure-time as contrast to work. Recreation and leisure occupied a substantial part of one's life and became symbols of freedom (Müller 1997, Opaschowski 1997).

Mobility has always been one of the most important human activities (Antrop 1999), although motivations for it have changed over time. Mobility and later travel were always connected with perceiving and experiencing new surroundings, places, and landscapes. As opposed to mere mobility, travel has been motivated by a whole host of motives: hunting, exchange of information, communication, trade, education, war, religion, and health.

It was only in the 17th and 18th centuries that travel was associated directly with pleasure and experience (Feifer 1986, Opaschowski 1996). 19th-century developments like the Romantic movement and technical innovations in transportation helped tourism to flourish. By the end of the 19th century, mobility and leisure had become interconnected. The groundwork for modern tourism had been laid (G. Tress 2000).

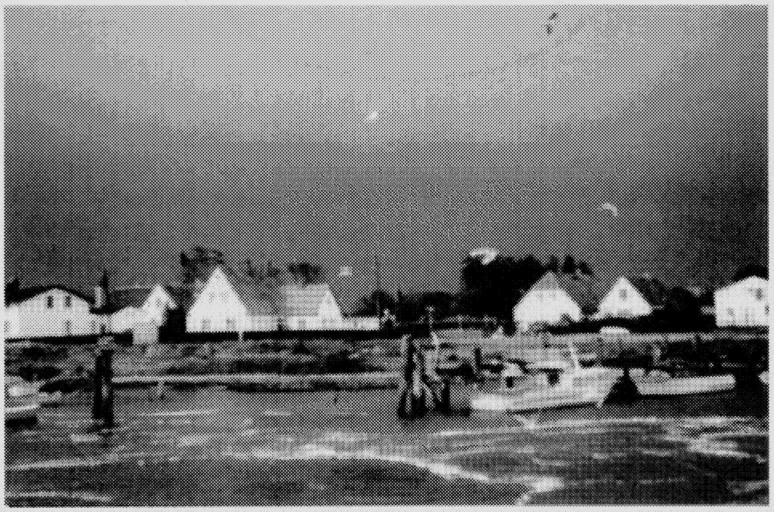


Figure 7.6-2: Tourism at sea coasts is very popular: The traditional fishing village Vitte (Baltic Sea, Isle of Hiddensee, Germany) (Photo: O. Bastian 1981)

Today, taking a vacation is the most important motivation for travel (Hughes 1996). Tourism is one of the human activities landscape ecology has had to deal with over the ever-changing course of human culture and history (Figure 7.6-2).

7.6.4 Tourism in the postmodern era

Today's tourism is a complex of expectations, motivations, and actions that are changing continuously. In this way, "tourism is prefiguratively postmodern because of its particular combination of the visual, the aesthetic, and the popular" (Urry 1990). In postmodern tourism elements of modernity have become blurred. Now tourism means the fulfillment of several needs at the same time. Not all needs are related to landscapes. But landscapes do play an important role in tourist activities in the postmodern era.

Tourism fulfils, for instance, the need for change; escape from the everyday; thirst for adventure, recovery or distance; and abandonment of relationships, duties and rules. It expresses the need for communication and the desire for solitude. Müller (1997) explains the phenomenon of tourism as the satisfaction of emotional and sensual demands that lie beyond the rationality of everyday life and work. Myths, rituals, and ideas of utopia are involved here. Motivations in tourism can be the search for something or the escape from something. Tourists want to be treated as individuals. The Romantic idea of tourism, the vision of unspoiled landscapes, still determines tourism. Longing for, seeing, experiencing, reaching and discovering landscapes is a fundamental motivation in contemporary tourism.

But the Romantic idea of tourism also expresses its dialectic: Tourists are looking for untouched nature and unspoiled landscapes, but this pristine state will be destroyed as tourists interact with the landscape. But what constitutes an unspoiled and untouched landscape for them? Authenticity plays an important role here, but is hard to determine in terms of landscapes. Different points in history, different stages of landscape development, and different utilizations of landscapes could be considered as authentic. And since experiences can be reproduced by different medias, it is not always authenticity that tourists are seeking (Feifer 1986, Urry 1990) – at least as it is understood by those landscape ecologists, who see authentic landscapes as those in a natural condition, untouched by the disturbing influence of man. But how can human influence be less authentic when human thought and action shapes landscapes and vice versa? For landscape ecology, the handling of the authenticity issue is a major challenge.

7.6.5 The ecological critique of tourism

Tourism is not only a very complex societal phenomenon, it is the world's biggest industry. For some countries, tourism is the most important source of income. In the European Union, tourism is the largest sector of economy. It is estimated that tourism directly employs 9 million people in the EU, representing 6% of total employment and accounting for at least 5.5% of GDP and 30% of total external trade in services. Tourism is seen as a major source of job creation in the years to come. Some sources estimate that travel and tourism jobs will increase by 2 million by the end of the next decade, and will represent over 9% of total employment in the EU (European Commission 1999, 2001, Opaschowski 1996, Rita 2000).

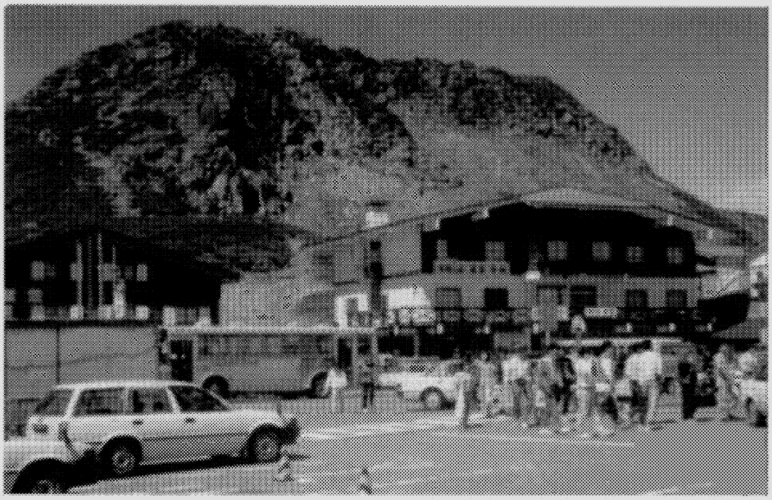


Figure 7.6-3: Tourism can lead to overexploitation of the sensible high-mountainous environment: Hotels in the Norikura Mountains (Japan) (Photo: O. Bastian 1993)

As with any human activity, tourism impacts the social and natural environment (Figure 7.6-3). But tourism has had heavier environmental consequences as its growth rate has exploded over the last few decades. It is also occasioned by the greater distance between the place where a tourist plans his/her vacation and where it actually takes place. Tourism thus causes environmental alterations in places where they might not have happened. The living conditions of permanent residents are impacted by the activity of temporary visitors. Moreover, tourism activities are occurring in attractive and unique places that are sometimes more sensitive to change than other areas.

From the mid-1970s through the 1980s, a critical attitude toward tourism developed that was based on perceived ecological damage caused by human activities. One of the first critics, Krippendorf (1975), called tourism a "landscape eater". The focus of the ecological critique of tourism was the increasing number of landscapes used for tourism purposes - with fundamental consequences. The question that arose was how to avoid increasing usage while fulfilling tourist demand. Landscapes were characterized as the capital of tourism: landscape elements such as air, sand, hills, beaches, forests, grass, snow and sea were free goods that could be used by everyone. The recognition that these resources were not unlimited led to the concept of "green tourism" (Hamele 1993, Jungk 1980, Krippendorf 1975, 1984) which demanded a deeper consideration of environmental and social concerns in tourism activities instead of solely focussing on economic benefit. But the concept became more of a market niche than a change of behavior.

Considering the huge amount of current tourist activities it would be utopian to expect that tourism activities could be done without any impact. Therefore, the task of landscape ecological research should be to support and develop strategies for tourism development that consider the interactions between humans and landscapes to a larger extent. Focussing solely on the negative consequences of tourism is not enough when landscape ecology would like to contribute to problem-solving in the field.

7.6.6 The development of second-home tourism in Denmark

Tourism is a large field of varying branches and activities. Second-home tourism demonstrates the general interrelationship of tourism and landscapes. The development of second homes is a good indicator of the explosion of tourist activities and their environmental consequences over the last few decades on an international scale.

Second homes are properties owned or rented on a long lease as the occasional residence of a household that usually lives elsewhere. Second-home tourism means the recreational use of second homes by their owners, friends or relatives of the owners, or vacationers who rent the houses. In Denmark, spending a holiday or a weekend in a second home is the dominant form of recreation and tourism. But second homes can be found in large numbers all over Europe (Table 7.6-1) – from small summer cabins to houses used year-around.

Table 7.6-1: Numbers and densities of second homes in selected European countries

	number of second homes	second homes per 100 inhabitants	second homes per km^2 of the national territory
Austria[6]	273,570	3.39	3.26
Czech Republic[6*]	395,800	3.91	5.01
Denmark[2]	214,131	4.04	4.96
England[3]	203,000	0.41	0.84
Estonia[3]	76,368	5.22	1.69
Finland[2]	439,000	8.30	1.26
France[4]	2,452,000	4.20	4.44
Germany[3]	130,700	0.16	0.36
Netherlands[2*]	80,811	0.51	1.99
Norway[1]	343,366	7.71	1.06
Spain[6]	2,923,615	7.45	5.77
Sweden[4]	380,638	4.30	0.84

Source: Data from the latest available figures from different national statistics departments; [1]1999, [2]1998, [3]1997, [4]1996, [5]1993, [6]1991, *including apartments used for recreational purposes

The second-home tradition in Denmark developed in the late 19th century. People from the larger urban areas discovered the recreational value of the small fishing villages close to the coast. They rented houses or built their own. The houses were situated close to the beach and had views of the sea if at all possible. In the 1980s, non-private usage, rentals to summer guests, exploded. Whereas the number of second homes in 1960 was about 51,000, it has increased to about 215,000 at present. Today, 10% of all households in Denmark possess second homes. In the mid-1990s, about 16 million overnight stays by foreign tourists in Danish second homes were recorded per year. Additionally, about 8 to 16 million overnight stays by owners in their second homes were estimated for the same period.

7.6.7 The environmental impact of second-home tourism

A study conducted from 1996 to 1999 investigated the mutual relationship between second-home tourism and the landscape in Denmark (G. Tress 2000). Both environmental consequences of second-home tourism as well as the tourists' motivations for second-home stays were considered. The investigation relied on two questionnaires of 628 second-home tourists in the research areas in Denmark. The first questionnaire was distributed to the second-home tourists during their stay in the second home; the second questionnaire was mailed to their main residence after returning from the second home. The term "**second-home tourists**" is used here to mean second-home owners who spend leisure-time or vacation in their own second home, and **second-home guests** who rent or loan homes for vacation. In addition to distributing surveys, data were collected about each home, its plot, and vegetation.

The study defines **environmental impact** as all kinds of physical consequences for the landscape resulting from the construction and use of second homes. In Denmark, conflicts over environmental protection of the coastal areas and interests of local residents predominate. The area that is used for second home purposes in Denmark is approximately 1.14% of the whole territory. More than 90% of all second homes are situated within the 3km coastal zone.

Environmental impact was measured in different ways: second-home density, consumption of area for second-home use and construction, disturbance of vegetation, dunes and soils, consumption of energy and water, travel distance between home residence and second home, and mode of transportation (car, bus, train, plane). A range of indicators was used to record the impact, such as number of second homes, number of beds and occupants per home, size of home and plot, extension of roads and paths, location of second homes in the landscape (in dunes, heaths, forests, agricultural areas), and others. But many indicators could only show impact measurable during the survey period. Comparison of maps and aerial pictures captured the long-term change of second-home tourism on landscapes.

In comparison with neighboring Scandinavian and other European countries, Denmark has a very high **density of second homes** used for recreation and tourism purposes (see Table 7.6-1). In particular the coast, is strongly impacted by second-home areas. From June to August, an average of 3,000 second-home occupants per km^2 lived in this area. In comparison, the municipality of Copenhagen has a permanent population density of 5,529 inhabitants.

The average size of a second-home is $88m^2$, but the range is from $24m^2$ for simple cabins to $252m^2$ for luxury homes. The average size of a second-home plot is $2,145m^2$. On average, 9% of the plot is built up (including driveways and parking lots). **Consumption of area** is indeed a major threat for Danish coastal landscapes.

Many second homes are situated in or close to dune areas or areas with sensitive vegetation. The occurrence of paths through dune areas is distinctly higher in second-home areas than in coastal areas without recreational housing. **Disturbance and loss of vegetation, soil and sand** are consequences of the intensive use of the paths.

Consumption of energy and water in second-home areas is a major challenge for local municipalities. High consumption of energy and water is seen in homes with luxury equipment such as pools, whirlpools and saunas (in about 25% of all second homes). Water consumption per year is up to 30% higher than the average water consumption of a Danish household (278 m^3 per year) without these amenities. Electricity is the main energy source in second homes for warm water and heating. Annual consumption varies between 2,000kWh and 40,000kWh. Water- and energy-saving equipment or ecological building materials are used sparsely.

Obviously, **private transportation** is highly valued in second-home tourism, but it is also the case that alternatives are rare as many of the second homes are situated far from public transportation. Although tourist density per km^2 during the peak season is in some areas almost as high as the population densities of highly urbanized areas, urban facilities such as shopping centers, social and cultural events, health services, and other services are almost completely missing. This monofunctional division engenders a high amount of traffic.

Second-home tourism in Denmark has a profound impact on the landscape and on the coastal zone in particular. But in general, it must be remembered that tourism is rarely the only land use in an area. Additionally, tourism's impact is measured in uncontrolled settings. Conventional experimental scientific principles cannot always be applied because of the complexity of the phenomenon. Causes and effects can at best be surmised rather than proven. An important question is whether environmental impact assigned to tourism is unique to tourism or whether other agents cause the same changes. The unique character of tourism's impact is where it occurs and the time at which it occurs (Butler 2000).

Although tourism touches social, cultural and environmental issues, it has been most valued for its commercial potential (Hughes 1996). Because of the enormous importance of second-home tourism in the Danish economy, one could indeed blame the tourism industry for exploiting coastal landscapes. When economic interest is high, as is the case of second-home tourism, environmental soundness can hardly be achieved merely by restrictions and political pressure. Yet, environmental concerns seem to have a lower priority in second-home tourism than other concerns. But what is the tourists' position? How do they feel about and react to the conditions for second-home tourism? What do they expect from the landscapes to which they travel? What motivates tourists to take a second-home vacation in Denmark?

7.6.8 The landscape's creation of second-home tourism

The reader will recall the introductory statement that tourism is not only impacting the landscape but landscapes are also inspiring tourism. This rationale dictated that the study investigate second-home tourists' motivations and perceptions.

All second-home guests were asked why they had come to Denmark for a second-home vacation. All those asked could give several reasons (Figure 7.6-4). For three-fourths of the second-home guests, the **motivation** could be found in the category landscape and nature. Typical answers were "because of the beautiful landscape", "because of the North Sea coast", or "because of the environment and nature". About a third of the guests mentioned that Denmark is close to their home residence and just under a third came because they appreciated the country and the mentality of the Danes. Prices, climate, adventure, or entertainment were seldom mentioned although they are crucial factors in choosing other destinations. Focusing on the activities of second-home tourists during their stay highlights again the landscape's role. Almost all tourists reported that their holiday or leisure activities include "recovery at the house", "staying on the beach", and "walking and hiking through the countryside/along the coast". For second-home guests who rent a home for a week or more, the location of the home was of crucial importance. For three-fourths of German guests and half of Danish ones, the location of the second home in the landscape was the reason for choosing it. Between 50% and 70% of all tourists prefer a second home situated in the dunes or close to the sea. A view of the sea is highly appreciated. Experiencing the coastal landscapes was a main motivation for second-home tourism. It is noteworthy that 48% of the European vacationers regard scenery as the main motivation for travel and vacation (European Commission 1998).

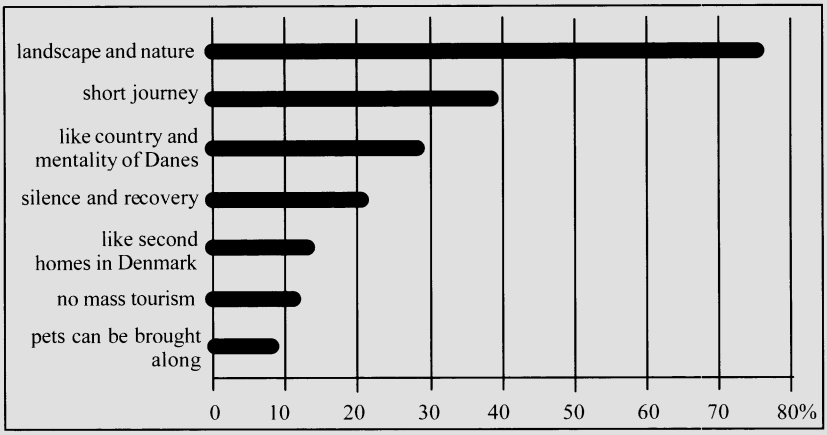


Figure 7.6-4: Second-home guests' reasons for travel to or within Denmark

7.6.9 Romanticization as landscape concept in second-home tourism

Perceptions of landscapes (see Chapter 5.5) result from differing cultural processes. Tourists' appreciation of landscape has different reasons and dimensions. Under the influence of Romanticism, travel became more and more motivated by the desire to experience landscapes (see sections 7.6.3 and 7.6.4). Urry (1990) wrote, "Emphasis was placed on the intensity of emotion and sensation, on poetic mystery rather than intellectual clarity, and on individual hedonistic expression". It was the uncultivated landscape, the mood, the solitude and the wild elements that made landscapes attractive. For urban residents, these Romantic ideals were connected to a change of place. Wild and unspoiled nature could not be experienced in towns. The longing for unspoiled landscapes was expressed by Rousseau's call for a return to nature in the 18^{th} century.

The development of the second-home tradition in Denmark is rooted in the ideals of romanticism. The earliest second homes were built in privileged places, close to the sea, beaches, and forests, and even today, people prefer these places for their homes. The plot was kept in a "natural" state. The natural-looking plot is perceived as a part of the unspoiled and uncontrolled landscape tourists are looking for. In the survey, influence of gardening was only found on plots of homes used solely by owners, not on plots of rented homes.

The explosive development in second-home tourism has led to a situation where landscape experiences shaped by Romantic ideals are getting harder to realize. No longer are all second homes located at privileged places, no longer do all have access to the beach. The solitude favored for experiencing landscapes has disappeared because of the increase in tourists. The sea view has been replaced by the view of the neighboring home. But up to the present day, the romanticization of landscapes has been the decisive engine of many forms of tourism - even when such expectations cannot be fulfilled. Nature and landscape based forms of tourism are to many a kind of mirror of society (Tonboe 1995). Landscape as a motivation for (second-home) tourism is an expression of people's demand for unspoiled, untouched and authentic environments. Romanticization is not negative; it does not symbolize an inability or unwillingness to perceive reality, but is rather an expression of the perception of landscapes in tourism shaped by tourists' values, expectations and experiences.

7.6.10 Planning and managing tourism landscapes

Romanticization of landscapes is not characteristic of all forms of tourism. Also, it would be a misunderstanding of the concept of landscape romanticization in tourism to assume that appreciated landscapes are always healthy ones and have de facto low environmental distress, or that tourism in general is dependent upon a healthy or pristine environment. Of course, visible environmental impact is hardly appreciated but even unsound landscapes can be romanticized. In the case of Danish second-home tourism, the landscape-tourism cycle could be applied successfully to the investigation of this topic.

When environmental impact and a clear predominance of second-home tourism along Danish coastal areas prevent such experiences as tourists would like to experience, the future of second-home tourism is threatened. From an environmental perspective, then, the **landscape's capacity** to cope with tourism activities will soon be exceeded. From a social perspective, the landscape is no longer able to fulfil tourists' demands and expectations. The landscape's ability to attract tourism diminishes. In economic terms, tourist activity then decreases - as has been the case in second-home tourism in Denmark since the mid-1990s. The numbers of overnight stays in second homes first stagnated and then decreased (G. Tress 2000). The reasons for this stagnation can be found not only in environmental concerns, overcrowded and densely built-up second-home areas, and increasing consumption of energy, water and area, but also in psycho-social and economic factors tied to the perception of landscape, its impact and the conditions for selecting a second-home vacation. Second-home ownership and rental has become expensive. Taking a one-week second-home holiday in Denmark costs more than a two-week trip to more remote destinations. Because of the huge number of second homes and tourists, second-home tourism has gained a negative connotation as a form of mass tourism. Landscape planners and managers must take into account the complexity and dynamism of tourism landscapes. Only by investigating tourists' perception and motivations along with tourism's impact can these challenges be faced.

7.6.11 Conclusion

When investigating tourist activities, landscape ecology research must apply a holistic approach. Landscape planning and management as well as the knowledge of solutions to the environmental consequences of tourism depend on the application of a **landscape concept that integrates physical and mental dimensions**. Only when specific landscape attributes that are attractive to tourists have been identified can there be understanding about what may need to be done to keep them attractive to tourists (Butler 2000). The landscape-tourism cycle can be used as a model in applied landscape ecology.

As tourism has become the world's biggest industry, the environmental consequences resulting from that business are of vital concern. Integrated landscape ecology studies in the field of tourism and recreation can contribute to successful landscape management. In planning, environmental, economic, and societal interests must be combined. Knowledge of the environmental impact and the motivations and expectations underlying tourist activity allows for a planning and managing process that respects different interests. Landscape planning (see Chapter 7.3) is then able to fulfill its task as a positive agent in landscapes and not as a reagent.

7.7 Nature conservation

7.7.1 Introduction

Nature conservation is calling for action. It has to make decisions and select areas for reserves, or has to choose among alternatives, when interferences cannot be avoided. Such decisions are based on assessments, which relate to values (see Chapter 5.3). Values are not constant and will be modified over time. Those changes are partly determined by the increase of knowledge but also by other processes, such as the political climate or social developments. As a consequence nature conservation will adapt and develop such new values. Nature conservation is a **normative discipline**. Its paradigms and norms underlay social processes and as a matter of fact are changing constantly. The objectives of nature conservation are different today, than they have been 20 or 100 years ago. This is not a critique, but necessary to realize.

If we take a brief look into the **history** of nature conservation, we will see how its philosophy has changed. The conscious conservation of nature, and of parts of it, as a social aim meanwhile has a long tradition. It roots in the perception of negative consequences of human interferences with nature. This phenomenon became apparent during the industrial revolution. It was associated to the technical progress that began to leave its marks in landscapes and to threat picturesque sceneries.

Based very much on the romantic movement in Europe, since the beginning of the 19th century (see Chapter 7.6.9), the vulnerability and the value of landscapes have been realized more and more. Nature conservation concentrated on grand and magnificent landscapes. In his writings Goethe emphasized the right of nature to remain untouched. He portrayed "natural monuments", and questioned their origin. His holistic approach to nature, seeing natural elements as a whole and not segregating them into their parts, had repercussions on Humboldt and influenced European natural science and nature conservation fundamentally.

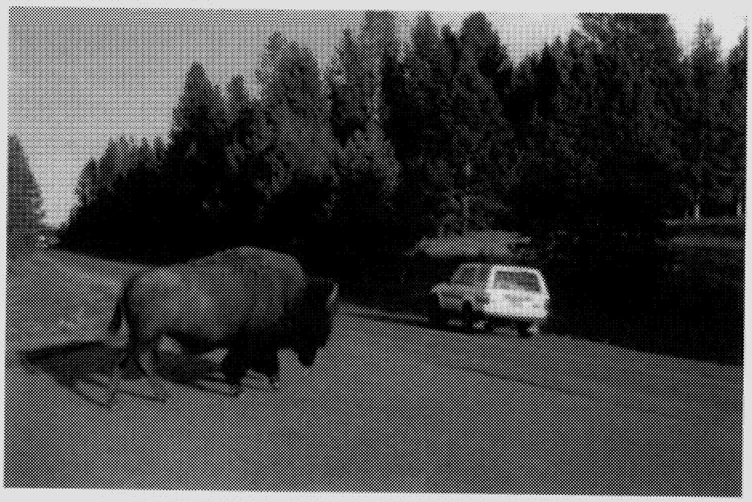


Figure 7.7-1: Yellowstone was the first national park founded in the U.S.A. in 1872 (Photo: O. Bastian 1991)

As early as 1836 in Germany the first natural monument was preserved by a local decree to protect a picturesque rock ("Drachenfels", Siebengebirge) against being destroyed by a quarry business. At that time, the ideas of conservation very much concentrated on extraordinary landscape elements.

In the United States the first national park (Yellowstone, Figure 7.7-1) was founded in 1872 based on a law enacted by the American congress. The philosophy still focused on extraordinary parts of nature, but the scale had shifted to landscapes. Many other parks followed. However, it took some time until naturalness per se became a major quality with the first Scandinavian national parks.

At the end of the 19th century (1880), Rudorff already spoke up for the protection of remnants of natural sites in Germany (Figure 7.7-2), some years later (1888) he introduced the German term "Naturschutz". He was opposing the increasing tourism and its consequences according to waste and constructions. In addition, he protested against traffic and industry.

This seems very modern, but definitely was not the common thinking at his time. During the 20th century, the **strategies** of nature conservation were continuously modified. It is remarkable, that the values and aims also differ widely between countries. Nature conservation had to adapt to circumstances linked to systems of economy and society. Various approaches developed parallel to each other.

Figure 7.7-2: Old and imposing trees can be an object of nature conservation: The ancient oak near Suckow (Isle of Usedom, Germany) (Photo: O. Bastian 2001)

Generally, nature conservation has to consider the environmental background and the history of different biomes, continents and landscapes. The political system had also a significant influence on the political side of nature conservation. The possibilities to utter ones opinion and to protest against pollution and against the destruction of natural habitats were obviously different during the 20th century as well, and of course also the administrative integration and importance of nature conservation.

The history and tradition of land use regulates strongly the composition of flora and fauna. The performance of wilderness and land use both are much related to landscapes and even to biomes. Highly valuable and rare biotopes in one landscape might be common in another one. However, as it is not possible to plan for whole landscapes where the interests of economy have to be considered as well, nature conservation concentrates on certain **areas of high value**. These are either rather natural or rather rich in species or hosting certain rare species.

During the second half of the 20^{th} century biologists started to realize, that the restriction to such marginal reserves would perhaps not help to maintain the natural qualities they were interested in. Based on island biogeography (McArthur and Wilson 1967) and on population biology new concepts were developed. Strong influence came through the concepts of patch dynamics (Pickett and Thompson 1978), minimum viable population size (Shaffer 1981, Simberloff 1988) and by metapopulation dynamics (Hanski and Gilpin 1991, see Chapter 2.8.2). Such theories can be seen as the fundamentals of the design of a **network of reserves**, which is the common strategy today. However, this network again has to be related to the ecological complexity of landscapes. Only then it will be a success.

7.7.2 Nature conservation and scale

Nature conservation must refer to the context of the object that is under focus. This is true for large reserves, such as national parks, that have to be conceptually integrated into the matrix of their surrounding. Buffer zones will be necessary. The interests and the traditions of local people that live close by have to be considered. But, this is also true for endangered populations of rare plants. Conservation strategies then will have to relate to the plant community, to important functional groups, such as pollinators, to site conditions, such as soil and microclimate, and to the disturbance regime. Neighboring areas have to be screened according to their potential for the dispersal of the target species. The spatial distribution of other populations of the same species has to be mapped.

This is why nature conservation is very much settled at the **landscape scale**. Conservation strategies will only be effective and successful, when they learn to integrate local activities into the landscape matrix. The subjects of nature conservation, species, communities and ecosystems are compartments of landscapes, with certain spatial and temporal qualities, adapted to a specific environment and to specific disturbance regimes. Many species and most of the communities that occur in Europe depend on certain anthropogenic activities. At the landscape scale not only threatening processes take place, but also the driving processes.

However, nature conservation has to integrate **different qualities of nature**. This starts with the genetic diversity within species, and reaches from the preservation of varieties, cultivars, and subspecies to the protection of the biosphere. The preservation of species and populations was always a major topic and will continue to be, but it can only succeed when also communities and biotopes are conceptually integrated.

Another point is the preservation of **non-living compartments** (geotopes). The perception of rocks or specific relief elements is emotionally stirring. **Rocks and relief** (Figure 7.7-3) can be modified or even destroyed and then be lost as a habitat but also as an aesthetic quality from a landscape. Preservation strategies therefore have to be widened and integrate also non-living parts of nature.

New concepts should also integrate the **soil**. This compartment, which is of basic importance for almost all our ecosystems, is merely regarded as a resource. Its specific and in some cases local qualities, the rarity and endangerment of soil types for instance or the biodiversity in soils are of almost no importance to the public until now, because nature conservation is still concentrating on biological qualities of landscapes. This conceptual shift would lead to **new paradigms**, which perhaps would see the subject of nature conservation as ecological systems with a variety of ecological qualities, integrating the soil, the water and the air.

Figure 7.7-3: Rocks and relief can be modified or even destroyed, and then be lost as a habitat but also as an aesthetic quality of a landscape: The famous natural bridge in the Bohemian Switzerland (Czech Republic) (Photo: O. Bastian 1981)

One consequence of the realization of the restrictions of local action is the **internationalization** of nature conservation. Knapp (1997) distinguishes four phases in this development:

- initial phase (-1945): the thoughts of nature conservation were established,
- phase of institutionalization (-1970): most institutions were founded and laws were enacted,
- phase of consolidation (-1990): nature reserves, laws and instruments were further developed and integrated into social processes, and
- phase of emancipation (after 1990): following the deep-rooted political changes during the last decade a new time of cooperation started.

In nature conservation the necessity of international contacts and communication is obvious. It is simply not possible to preserve migrating species in one country alone. The design of reserves has to consider, how species are distributed. Trends of populations and of ecosystems have to be noticed. The control of invasive species (see Chapter 4.3.2) is another point. In addition to this, and in some cases having direct impact on the preservation interests, the economic interactions between countries became so close and intensive, that we can no longer look at questions of conservation in an isolated way.

Institutions and contracts are regulating the international information exchange. Since more than 50 years international programs and organizations, such as IUCN, UNEP, MAB, and non governmental organizations (NGOs), such as WWF, are working on a global scale. The "Ramsar Convention" on wetlands (Ramsar, Iran 1971) was a landmark in this development. Soon it was followed by the "Convention on International Trade in Endangered Species of Wild Flora and Fauna" (CITES, Washington, D.C. 1973) and many other international contracts as the "Convention on the Conservation of Migratory Species of Wild Animals" (CMS, Bonn 1979).

High impact on politics then was affected by the United Nations Conference on Environment and Development (UNCED), the "earth summit", in Rio de Janeiro in 1992. Among other influential contracts, there the "Convention on Biodiversity" was signed by 159 nations. This convention is the consequence of the fact, that we realize a "crisis of biodiversity", meaning a global loss of species, during the 1980's (Ehrlich and Ehrlich 1981, Wilson 1985). We are facing the 6th strongest extinction event during the earth's history (Gorke 1999), but this is the first time, that this is not caused by a large cosmic impact. This observation goes along with the fear of losing ecosystem functions when losing biodiversity. The convention emphasizes that the preservation of biodiversity is not only of concern in the tropics, but throughout the world. The new quality of this convention is that the contracting nations signed to identify components of biological diversity important for its conservation, to monitor these components and to find out processes and activities that have significant negative impacts on biodiversity (Article

7). There was consent to establish programs for research as well as for education and training in this field (Article 12).

The global changes of the environment show, that **nature conservation cannot be static** (Kerr and Currie 1995, Pearce and Perrings 1995). It has to react to the dynamics of the system it is interested in. Changes will occur according to natural site conditions, to species composition and to disturbance regime.

Temporal scales are also important when landscape history is concerned (see Chapter 4.1). The evolution of cultural landscapes went along deep changes in the composition and distribution of landscape elements. New communities established, other ones, that have been natural, vanished and were replaced by anthropogenic land use types. The planning and application of restoration and compensation measures has to consider this historical background. The creation of new elements that have not been native in the respective area before is problematic.

However, dynamic processes are important for ecosystems, communities and populations. Static conditions do not occur in nature. Temporal variability is a driving mechanism of evolution but for the maintenance of populations as well. Temporal niches are obvious, as the light gap for geophytes in European beech forests during spring, but until now management for annual temporal variability is not common generally adapted in nature conservation.

This is perhaps even truer for temporal variability over longer periods. **Succession** in many cases is regarded as a negative process, because it modifies the community and perhaps valuable species might get lost. This philosophy is mainly found in Europe, where space is limited. Nature conservation here is still rather conservative and wants to preserve a certain status quo. This causes logical conflicts, because the environment and the land use regime is not static, but is considerably changing.

A new direction in nature conservation focuses no longer on the protection or the connection of left over areas, which are of no economic interest, but claims the **preservation of processes**. Conservation strategies like this have been developed in Germany long time ago, but remained very week, aiming at the general preservation of landscape properties (natural parks, areas of landscape conservation, etc.) without powerful restrictions for the economic and infra-structural development. But, how to install or promote certain processes, as the reduction of quantitative aspects of nutrient cycles, how to encourage land users to act in a certain way. One approach to reach the goal of managing processes at the landscape level is contractual nature conservation. In this case, the users of the landscape, farmers and foresters, are paid for a certain land management. **Economic incentives** are used to direct the management and to reach desired effects. In addition, marketing initiatives are very promising, for instance to support ecological land use, or to maintain agriculture in marginal areas. Such initiatives can contribute to preserve resources and maintain or even enlarge species diversity indirectly, even if the major target is the production of food.

7.7.3 Preservation of biodiversity

Today, many practical works deal with the preservation of biodiversity (Falk et al. 1996). In assessments on the environmental compatibility (see Chapter 7.4) biodiversity became an important criterion. In landscape planning (see Chapter 7.3) and in preservation management it is highly ranked as well.

Not all the species can equally be preserved. Target-, indicator- or key-species have to be identified to concentrate on. Besides specific species, communities or ecosystems, modern nature conservation tries to preserve biodiversity in general topic as well. However, concepts that acknowledge diversity per se as a value and integrate it into the planning of conservation strategies are rare (Noss et al. 1997). One reason for this is that the term **biodiversity** is not clearly defined and used ambiguously. It seems clear, that biodiversity not only addresses species diversity, although this is an important issue. Species are just one option to classify organisms, others may be more important for certain aspects of ecosystems (functional groups, growth and life forms, age classes). Then, organisms are only one category of levels of organization in nature. Others contribute strongly to the diversity of landscapes. The diversity of more complex landscape, such as communities or ecosystems, has to be taken into account as well. This is already reflected in the Convention on Biological Diversity (CBD), but is not general consent. In addition to this, not only the number of elements or units, such as species, is a criterion for biodiversity, but also their resemblance or dissimilarity. This differentiates biodiversity into quantitative and qualitative diversity. The most important aspect, however, then will be the third category, which is the functional diversity. This leads to biocomplexity and further on to **ecological complexity**, if one integrates abiotic ecological compartments (Beierkuhnlein 1998).

Nevertheless, the research mainly concentrates on the mapping and analysis of **species diversity**. But even there, the knowledge about real distribution patterns of biodiversity in normal landscapes is small. We know a lot about the hot spots of biodiversity, but the diversity of species throughout common cultural or natural landscapes is widely unknown. Special problems occur, when species are gradually loosing importance in an area. They may still be found at different places, but have changed significantly in their dominance patterns. This is hard to detect. However, such shifts in species abundance or dominance might be important for the maintenance of ecosystem functioning.

The preservation of biocomplexity and perhaps more general of ecological complexity as well would be a new paradigm for nature conservation. To maintain the functioning of ecosystems and landscapes will be an important task in the future. The loss of species diversity might affect the ecological services that nature offers to mankind.

7.7.4 SLOSS

An important aspect in conservation practice according to biodiversity is the size and delimitation of preserves. Should nature reserves be large or small? Behind the acronym SLOSS, the crucial question: "**Single Large or Several Small?**" is hidden. What will bring more benefit: the design of only few but large sized areas or the protection of many but small reserves? A certain influence of size on species diversity of reserves is rather obvious, but other factors will modify this relation. **Edge effects** (see Chapters 2.3.2 and 2.8.5), for instance, will increase environmental heterogeneity. That is one reason why small isolated biotopes are so rich in species. Species that are closely tied to the characteristic environmental conditions of a landscape element, which are not to be found close to its edge, will prefer larger patches. Fragmentation (see Chapters 2.3.7 and 2.8.8) might reduce the portion of the central area strongly (Figure 7.7-4).

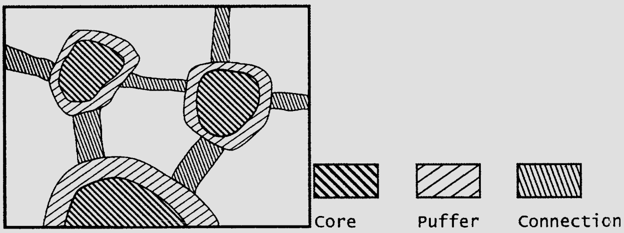


Figure 7.7-4: Fragmentation may cause much higher losses of interior habitats of specialized organisms than this becomes evident in the total loss of patch area. The total loss of area of a landscape element will perhaps be not large, yet the functional impact can be strong

Nature conservation tries to achieve a certain probability to reach its goals. One indication for this success would be a certain stability of the communities in focus. The assumption that **stability** (see Chapter 5.1.2) **and species richness** are connected has a striking persuasive power, but there is an intensive discussion going on since decades about this topic. Until now, species diversity is regarded as an indicator for persistence of communities.

Nature conservation is reduced in cultural landscapes to remnants of natural biotopes or of communities with high biodiversity, which are spread throughout the landscapes and do occupy only a small area. This is not true in natural or semi-natural landscapes (Figure 7.7-5), which can be found in sparsely settled areas of high mountains, of boreal region, of tropical rain forests, in steppe landscapes or deserts. There conflicts with land use are less important and the design of larger reserve areas is possible. Local population in such **marginal regions** often is traditionally based on subsistence in agriculture and forestry and adapted to the natural conditions of their environment. Conservation projects ought to integrate human traditions and interests. Then, large reserves can be designed successfully and will last.

The theoretical background behind the question whether single large or several small areas should be protected, is the **theory of island biogeography** (McArthur and Wilson 1967, see Chapter 2.8.2). According to this theory, the size of an area strongly influences the number of species. A second aspect is the distance between areas. The third point, which is of interest, is the existence of stepping stones between a continental source and an island sink or target.

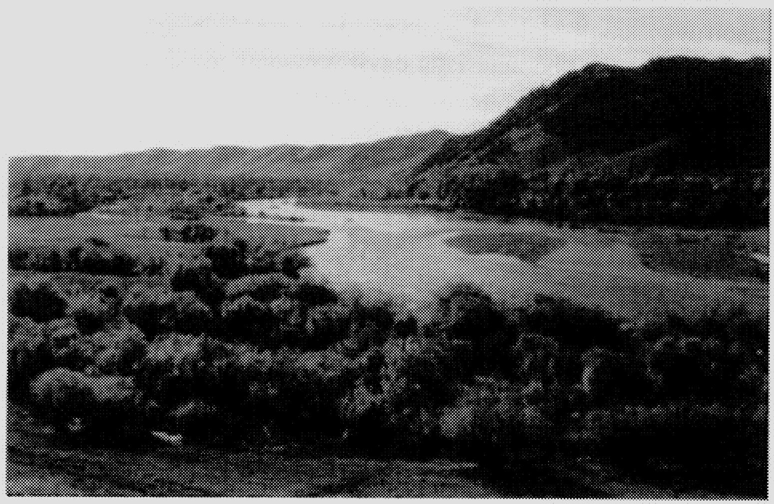


Figure 7.7-5: Remote areas with a more or less pristine nature are favorable to establish large protected areas: The Centej Mountaions (Mongolia) (Photo: O. Bastian 1994)

Boundaries and ecotones (see Chapter 2.6) are important for species, which require both, the site conditions of one and those of a neighboring landscape element. Nevertheless, these transitional areas are rarely mapped or protected explicitly. Paying attention to transitional zones makes management much more complicated. **Transitional landscape structures** should be considered also in the design of reserves. If the influence of the surrounding matrix of a reserve is found to be negative, if it has to be protected against detrimental processes, such as nutrient input or disturbances of animals, **buffer zones** have to be added to the reserve to enlarge the surface and to reduce the edge effects. This will make the reserve larger than its core area.

7.7.5 Networks

Nature conservation has to integrate spatial and temporal qualities of landscapes. In spatial patterns and mosaics besides the site conditions, the **disturbance regimes** are of a crucial importance (Pickett et al. 1996). Land use changes in general and mainly the abandonment of traditional agricultural land use, at low levels of technical and chemical intensity, are the major threats to species in Germany (Korneck and Sukopp 1988). Other functional impacts go along with the loss of connections and with the loss of stepping stones due to the growing uniformity of landscapes (Figure 7.7-6). The loss of a patch or a landscape element itself may be not severe according to the number of species or individuals that are directly affected. But, if this area was of functional importance within the landscape matrix for movements and migrations, for short-term establishment of small populations or as hiding place against predators within an open landscape. The effect of this loss will also influence the surrounding matrix and neighboring patches of a similar kind.

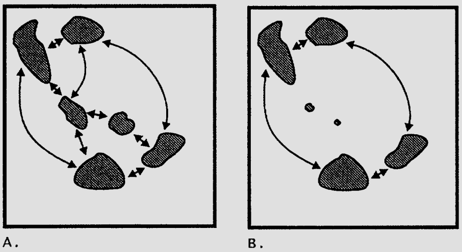


Figure 7.7-6: Temporal change in functional connection and network. At time A there is strong exchange between patches. At time B reduction of two central elements leads to the isolation or exclusion of small elements (e.g. populations) and a weak exchange (e.g. gene flow, individuals, pollination). Stepping stones loose their function beyond certain threshold values for minimum area

The functioning of landscape elements depends a lot on the **connectivity** (see Chapters 2.3.7 and 2.8.4) between patches of the same type. Connections can be spatial, temporal or just functional. A **system of biotope connection** must consider four decisive qualities (after Jedicke 1994):

- large reserves that function as a reservoir for species (this has to be designed on the basis of the requirements of the most demanding species),

- stepping stones between isolated habitats (they serve as temporal refuges during the migration of species),
- corridors to promote migrations and the transport of diaspores, and
- reduction of land use intensity within the landscape matrix.

The attraction of this concept appears to be somehow dangerous as well. It supports the impression, that we have sufficient knowledge to manage biodiversity and to preserve species. Perhaps networks will contribute to improve the population structure of certain species. Which one? That one that we will select? Do we really know enough to design such systems for the entire species pool of landscapes and regions? It has to be kept in mind that the capacity of vectors not only depends on spatial circumstances. Vectors may be spatially concrete (hedgerows), but not necessarily. They may also use certain media (wind, water) or other organisms (birds) that can easily trespass the distances between isolated patches.

The German Federal Agency of Nature Conservation (2000) has the political target to preserve approximately 10% of Germany for nature conservation networks. Within the European Union since 1992 the so-called **"Fauna-Flora-Habitat"-directive** of the council of the EU has to be implemented that concentrates on the establishment of a coherent ecological network of special areas of conservation ("Natura 2000"). The term "fauna-flora-habitat" is a little bit misleading, as the biological definition of habitat is always species-related, each species has another habitat that overlaps with others, so that this would not allow a spatially discrete planning. However, the network shall conserve natural habitat types as well as animal and plant populations of international importance. The members of the EU have to contribute a certain percentage of their surface to this network.

7.7.6 Competing values

Nature conservation as a normative discipline integrating societal needs and wishes. Aesthetic and ethical values play an important role in nature conservation. In addition to this economic aspects will influence nature conservation as well. The costs and the benefits of nature conservation have to be analyzed, but the economic value of nature itself is not already really known (Montgomery and Pollack 1996, Pearce and Perrings 1995).

At this point, we have to draw a clear line between natural sciences and nature conservation. Competence in this field is not restricted to scientists, when economic, ethic and aesthetic arguments count as well. Decisions have to underlay a democratic process. Landscape ecology can contribute facts for decisions and analyze consequences and success of conservation management. Nevertheless, it cannot make the decisions (see Chapter 7.2).

To be normative, is generally also true for other land using disciplines, such as agriculture or forestry. But, their norms are clearly economic and therefore easy to measure and to evaluate. In nature conservation a variety of different, and in some cases opposing, standards and value systems exist. One action or management technique might be beneficial to a specific aspect but detrimental to another one. Therefore, decisions require, even within nature conservation, communication and perhaps mediation to identify a common strategy. This field of evaluation is crucial for nature conservation. The conservation value might differ a lot depending on the selection of objects and criteria. The weighing of certain criteria, however, has to relate to the individual landscapes where they are applied.

The selection and the evaluation of specific natural qualities has to be done in a way that can be proved by others. As there will be never be absolute objectivity but only inter-subjective agreement about the decisions to make, this is an important fact.

7.8 Historical landscapes and landscape elements

7.8.1 Introduction

Landscapes are changing and have always been. These changes can be gradual or sudden, periodical or unique. What we see today, is the result of many processes and mechanisms that have been effective during different time periods. Thus, landscapes are characterized by historical influences (see Chapter 4.1). Today, the influence of mankind is reflected in agro-industrial landscapes but also in more natural regions. According to the degree of human transformation of landscape compartments, differentiating factors are the duration of settlements or civilization, the technical knowledge of the society, the social system (e.g. rules and laws for land ownership) and the economic standard of living (Simpson and Christensen 1997). Nevertheless, the contribution of historical human activities to recent conditions and landscape properties differs a lot between landscapes.

In former times, human influence was affecting landscapes and ecosystems at other spatial scales than today and than expected for the future. Pollution and globalization are affecting landscape processes with an increasing speed and magnitude. Besides problems in species adaptation, such processes often result in accelerated within-system turnover rates, as regards species composition, nutrient, water and energy cycles. System and landscape change is faster today, than this has been in the past (Figure 7.8-1).

Landscape evaluation has to be related to both the current and the historical background. This chapter concentrates on the historical influence of mankind on landscape properties and on resulting implications for nature conservation. It will highlight various qualities of human impact and outline their historical role. Based on the understanding of historical processes and their effects on landscapes, we can detect and evaluate historical landscape elements and develop tools for landscape management and preservation.

Testimonies of historical land use forms and of human constructions are widespread in landscapes. Some of them are obvious and abundant, others are inconspicuous and rare. Some of them are still used and further developed, others are abandoned, ruined or decayed. When aiming at protection of historical remnants of land use or of other human activities, the major problem nowadays consists of defining the appropriate temporal scale of reference, and to identify modifications of a certain status that reduce its conservation value.

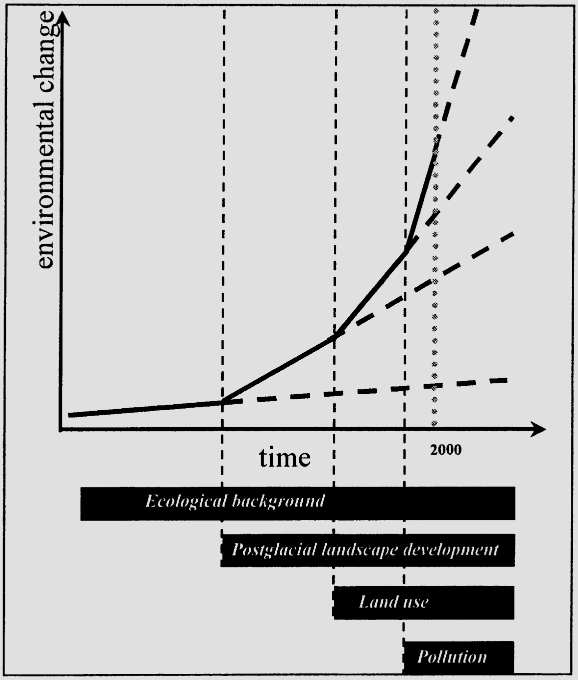


Figure 7.8-1: The velocity of environmental change has been modified by regimes of processes induced from the natural environmental background and by human impacts to the biosphere. Natural processes have been contributing to a much lower rate of change than anthropogenic processes

7.8.2 Relief and water bodies

Human have modified the surface of the land aiming at a better framework for land use, infrastructure and settlements. The change of land surface goes along with a redistribution of materials, such as substrate or stones.

Anthropogenic infrastructure has left traces in landscapes long ago, and relicts can be found even in forest areas with no current roads. Man always tried to find the shortest or most convenient way for travelling between villages. Speed was restricted by horses or cattle used for draught. Slopes were not completely avoided. The animals were strong enough to trespass them and other options would have taken up to much time. As a result, steep roads developed, that offered the starting point for channel erosion. These roads eroded consecutively deeper, until they were abandoned and reestablished parallel to the former one. Today, we can find remnants of such infrastructure everywhere in hilly or mountainous areas across Europe. In many countries of the southern hemisphere such roads are still in use. Other infrastructure elements of historical origin, such as railroads and canals or ancient bridges, are more obvious in their impact on landscape structure. In many cases, old infrastructure elements are out of use, but have regained romantic attraction, which allows to integrate them into the concepts of tourism (Figure 7.8-2).

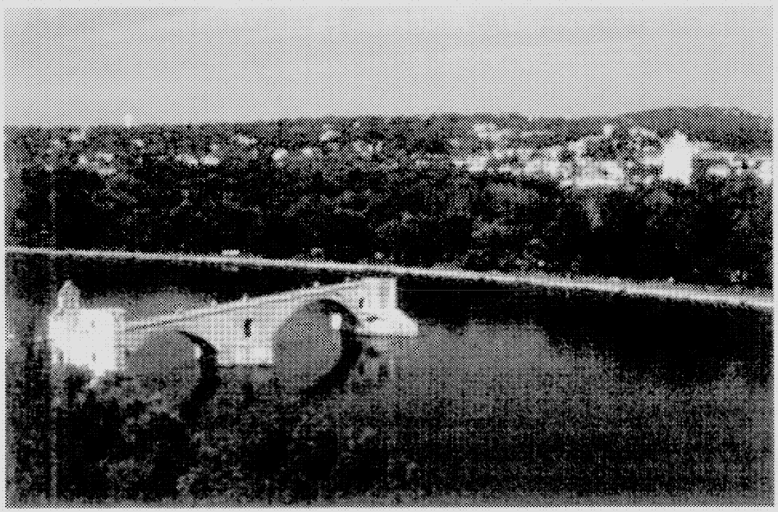


Figure 7.8-2: Old infrastructure elements can have a romantic attraction which allows to integrate them into concepts of tourism: The famous Avignon Bridge (France) (Photo: O. Bastian 1995)

Spatially more important are modifications of relief due to **agriculture**. They are correlated with tillage of substrate rich in skeleton and stones.

Ploughing of fields accelerates sheet erosion or wind erosion. Due to mechanical sorting during ploughing, stones are transported to the surface. To facilitate further cultivation, these **stones** were taken away and deposited at the margin of the field. Such margins developed frequently to hedgerows because this strip at the edge of the field could not be used. Nowadays, the relicts of former land use techniques, the deposits and hedgerows, became obstacles and were removed. This led to a loss of structural landscape diversity and to fragmentation. The creation of morphological variety was only a side effect of agricultural activities. Farmer were more interested in the compensation of morphological irregularities. At steep slopes, they tried to reduce the inclination to avoid soil erosion. This was leading to the development of **terraces** (Figure 7.8-3). In arid and semiarid regions, irrigation and the economic use of water was the major driving force for the construction of terraces with low or even no inclination at all. Another example for geomorphological effects of land use is the construction of **ditches** for drainage or irrigation. According to their function, ditches had different influence on the landscape. The drainage of mires and wetlands was the prerequisite for further cultivation. The reduction of soil moisture made these sites accessible. Some landscape elements, such as ditches for irrigation, required an immense effort for maintenance (e.g. "Wale" in Southern Tyrol, Italy). This was of minor concern in the past, and still is in developing countries, where labor costs and salaries are low, and where sufficient manpower is available to maintain these constructions. In industrial countries, such labor-intensive forms of land use were abandoned during the 20th century.

Other examples of historical landscape engineering are to be found in **riverbed regulations**. Smooth riverbanks were manipulated, natural dynamics were diminished, meanders disappeared. On the other hand, new constructions, such as wears and dams, were introduced, that reduced the landscape corridor function of rivers. These interventions did not only affect the river itself, but also the groundwater regime in valleys, the high water levels, the run-off and the seasonal floods. Such constructions are generally disapproved today from the nature conservation point of view. However, in some cases, remnants of old trials to control water flow are regarded valuable, mainly when new water bodies were introduced in connection with specific land use techniques, such as mill ditches. Some landscape elements of high ecological value, e.g. oxbows and dead river beds, are even the result of straightening and regulation of rivers.

Besides technical restrictions and high availability of manual work, also **ethnic and religious traditions** strongly influenced historical land use. In Central Europe, artificial ponds for fishery are concentrated in catholic regions, where the consumption of meat was forbidden during fasting periods. These ponds became important biotopes for water birds.

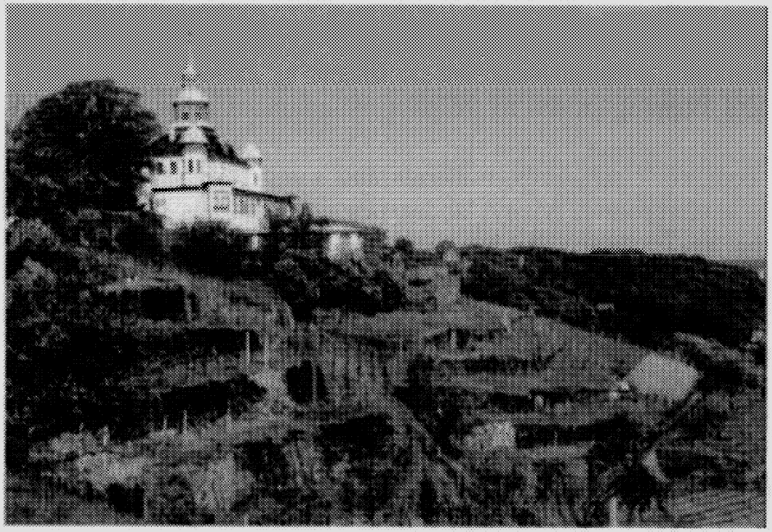


Figure 7.8-3: To compensate morphological irregularities, and to avoid soil erosion, terraces were developed: Vineyards at Elbe river valley slopes (Radebeul near Dresden, Saxony, Germany) (Photo: O. Bastian 1999)

In contrast to the redistribution of material, quarries, gravel pits and **open cast mines** are the results of removal of substrate and bedrock. In former times, mining was controlled by the power of technical advices and restricted to local activities. Here again, with the technical development of the 19th century, and mainly driven by the invention of vapor power machines and electric light followed by combustion engines, a new dimension of human impact was reached. Limits of accessibility and transport could be overcome and new landscape elements evolved. Open cast mining, for instance, led to a new dimension of anthropogenic landforms and biotopes. Some species found new habitats in such areas. Other could compensate the loss of natural habitats, such as gravel fields in braded rivers. The ascent of ground water is another factor that changes site conditions in open cast mines after the end of the exploitation. Lakes are forming and add landscape elements that were perhaps lacking in these areas (see Figure 7.11-2).

Quarries increase the ecological diversity in many landscapes offering habitats with extreme site conditions for various groups of species (birds, reptiles, amphibians). Depending on the composition of the bedrock and on exploitation technique, quarries may produce large amounts of debris and waste, which have to be deposited, scattered or piled up. Dumps of slate quarries are a prominent landscape element in the Central European metamorphic slate mountains ("Thüringer Schiefergebirge"). During slate exploitation, only a small portion of the bedrock can be used and 90% of the parent material has to be dumped. This produces new biotopes with extreme environments and very slow succession. Such sites serve thermophilic species (e.g. snakes as *Coronilla austriaca* or lizards as *Lacerta agilis*) as island habitats and stepping stones to trespass mountainous areas with rough climate.

Hard coal, rock salt, ores, minerals and some sorts of rock are mined preferably underground. Many landscapes show **relicts of underground mining** that are protected and in some cases used as tourist attractions. The importance of such caves for winter quarters for bats is well known. Temperature and air humidity stay nearly constant throughout the year and offer frost free refuges for these endangered mammals.

7.8.3 Soil

Soils were also modified and reshaped by human activities. This is not as evident as changes in relief. Modifications of soils can be interesting relicts of former land use. We can deduce from soil profiles, which kind of historical land use has been applied, whether the site has been ploughed before, whether occasional burning occurred.

Most human activities that are documented in the archive of the soil were aiming to improve its fertility. **Fertilization** is mainly regarded negatively under the perspective of nature conservation, as it led to an eutrophication of ecosystems and landscapes. If the capacity of the soil to retain nutrients is low, then the input of organic matter (for instance as part of the historical German "Plaggenwirtschaft") will improve the cation exchange capacity. This import of organic carbon is combined with an export from other systems. In many cases, as a consequence, these sites will impoverish and degrade. Short distance transports within the field was practiced by the medieval ridge and follow management ("celtic fields", "Wölbäcker").

Even in the humid tropics, relicts of such management strategies with accumulation of organic matter in soils can be found. The anthropogenic "Terra Preta do Indio" soils are located in a matrix of infertile oxisols. These relictic soils can be managed in a sustainable way. They are very fertile although they are rather old (Pre-Columbian) and have developed under extreme tropical conditions (Eden et al. 1984). "Hot spots" of nutrient enrichment due to human activities can also be found in African savannah-ecosystems (Blackmore et al. 1990). Besides fertilization and the integration of organic matter, people tried to improve physical properties as well, such as infiltration, aggregation or compaction. Many of those activities are no longer practiced, but can be reconstructed by their effects documented in soil profiles. Soils that document these land use practices are of socio-cultural value.

In some cases, the **degradation** of soil functions and the loss of substrate may also be an interesting topic. Most heathlands are the result of non-sustainable land use. The "Lüneburger Heide" in Northern Germany, an area that is very attractive for tourists, can only be understood as the result of an ecologically non-adapted overexploitation. Causes of degradation are the export of biomass (living biomass or dead material and litter) without compensation of this nutrient loss to the ecosystem. Many land use systems concentrate on the cultivation of profitable crops on well suited arable land and on the improvement of such sites. Sites with low productivity then, are mainly used to take biomass and mix it with manure which is spread on more fertile ground. The long-term export of nutrients and carbon further degrades low productivity sites and emphasizes environmental differences.

Other causes of degradation are the induction of **wind and water erosion** by logging forests or removing vegetation structures. In dependence of relief and climate, different forms of erosion may predominate and create new landforms, which can have a certain aesthetic quality. This may be true for extreme degraded sites, such as badlands, but depends strongly on individual perception. Degradation generally restricts the options for future decisions and enhances specific land use types. Forms of use then may be adapted to reduced nutrient capacity or water retention of the soil. Again, such land use types, and the ecological knowledge that is reflected in them, can be landscape-specific and ought to be preserved.

In European landscapes, erosion was high during the late medieval time. From paleopedological investigations we obtain the information, that during approximately 50 years around the year 1350 excessive channel erosion occurred. This degradation went along with strong social and economic problems (Bork et al. 1998). As the eroded material has to be deposited somewhere, erosion creates new substrates. The thick layers of colluvial sediments of many European valleys were induced by human activities and corresponding intensive erosion within the catchments of the rivers.

7.8.4 Species, communities and ecosystems

Looking at species, and pondering about their role in historical landscapes, human influence becomes strikingly obvious. Species diversity in Europe is strongly connected with land use history and land use diversity. Plant communities developed as a reaction to regular agricultural activities. Some of these communities are depending on certain techniques and seasonal rhythms of land use. Even as early as in the 1960s, changes in the species composition of Central European plant communities on arable fields were noticed (Tüxen 1962).

The role that humans play for the **extinction of species** is an increasing one. This is not only true for Europe during the 20^{th} century, but also for other continents and mainly for vulnerable island flora and fauna. For instance, the bird species diversity of Pacific islands was immense until the Polynesians reached the islands 4000 to 1000 years ago. A specific bird fauna had evolved on these archipelagos. Most birds were not adapted to predators. Despite its low technical standard, this civilization wiped out 15% of the global bird fauna (2000 bird species) (Steadman 1995). These historical landscape objects are lost forever.

The presence of man also plays a role for the **dispersal of species**. Traditionally, neophytes and neozoons are defined from an Euro-centric point of view with the discovery of the "New World" in 1492. Compared to pre-settlement species composition in Central Europe, much more species have been introduced from neighboring regions before and perhaps even after, as we do not have complete records on this process.

So, what are historical communities or species? Natives? Archaeophytes? Ruderals? And are certain neophytes, which have been introduced in former times, historical or not? In many cases, where the process of introduction is documented, we can distinguish between introduced species and natural species.

Introduced species are species which have been transferred from one region to another in a conscious and planned action. Introduced species may be seen as a problem, but on the other hand, introduced species may be valuable elements in historical landscapes (Abrams 1996) and correlated to specific land use types. Nearly all field crops and fruit trees are introduced. Here, the breeding of **ancient cultivars and varieties** is of interest which are replaced by more productive others. However, the preservation of intraspecific genetic variability is an important task for landscape conservation. This is also true for domestic animals, where local races became extinct in many cases (Figure 7.8-4).

Today, Central American pines (e.g. *Pinus radiata*, *Pinus caribea*) are widespread in tropical and subtropical regions of the world, if there is sufficient humidity. Eucalypt forests (e.g. *Eucalyptus globulus*) can be found everywhere in Mediterranean climates. Such introduced tree species replace natural ecosystems and strongly affect landscapes, communities, functions and processes of ecosystems. *Robinia pseudacacia* has become an integral part of the European forests. The species reproduces successfully and is a strong competitor under certain site conditions, altering soil conditions by its mycorhizal fixation of nitrogen. Many introduced species, which can be seen as a part of the local floras today, could be listed here.

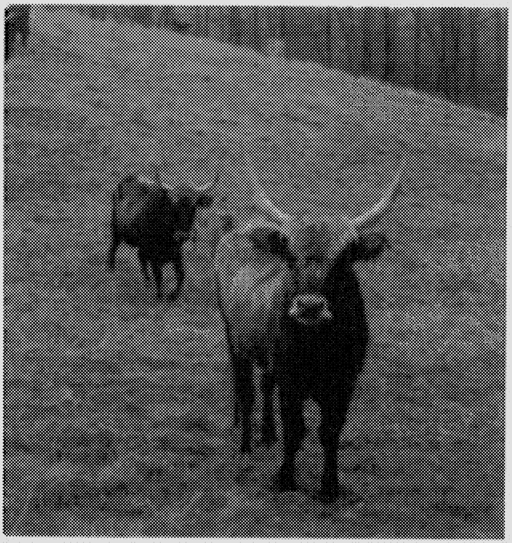


Figure 7.8-4: The preservation of old or local races of domestic animals belongs to the tasks of nature conservation, too: A cattle race similar to the extinct aurochs (near Döbeln, Saxony, Germany) (Photo: O. Bastian 2000)

7.8.5 Conservation of cultural landscapes and landscape elements

The specific traits of cultural landscapes are a high intensity and a long history of human influence (Haber 2001, Naveh 1995). Cultural landscapes, where social and economic interactions among people are reflected in the landscape context, exist in all regions of the world. They do not only include landscapes where resident human populations occur, but also landscapes with migrating nomads, when the influence of man is decisive for certain landscape conditions. One could ask, whether a landscape without human influence exists at all. Perhaps in some high mountain areas, in some deserts, in the Arctic, one will find landscapes, where humans did not change decisive qualities of the landscapes until now. Though, if one defines landscapes as regions with comparable environmental background and ecosystems and includes human activities into the concept, the term "cultural landscapes" becomes useless (see Chapter 1.1).

Changes in landscapes are directly correlated with the **development of human societies**. The preservation of a specific state is difficult to imagine, though. One could hardly select one certain time frame as historical, and suggest that this composition or structure ought to be restored. Modern approaches in landscape management rather aim at preserving natural variation within certain bounds.

Generally, the interaction between human influence and landscape pattern can be regarded as cause and effect. Then, human influence is interrelated with the occurrence of specific landscape patterns. Settlements for instance require drinking water, wind protection, arable soils, wood for burning, raw materials for construction and clothing. On the other hand, settlements influence landscape patterns, create specific anthropogeneous patterns and modify others. This occurs at different scales. We can regard anthropogenic land use as **disturbance regime** (Jentsch et al. in press). Such disturbance regimes have to be conserved for the protection of historic landscape elements or landscape structures.

The conservation of historical states in landscapes is an illusion, because the conservation of a certain status quo has to face global change. Neff (2000) has developed a deterministic model for vegetation dynamics in Mediterranean landscapes integrating perturbation and competition regarding space and light regime. Mediterranean landscapes are strongly modified by a variety of cultures over long time periods. Many sites can no longer reach former climax vegetation, because soil properties are degraded irreversibly. Also today, irreversible and reoccurring disturbances are part of these ecosystems. The diversity of landscape elements and species in managed landscapes is closely connected to the disturbance or land use regime (Szaro and Johnston 1996). If new disturbance regimes (or land uses) are introduced, species will need a certain time to react and to adapt. Under this assumption, the rapid changes of our recent landscapes have to be regarded critically. Then, the protection of historical structures is a tool to preserve species diversity and biotic resources in co-evolved ecological communities.

Birnbaum (1994) differentiates four types of landscapes according to **historical features**. The first landscape type can be associated with an historical event, a well-known person, or certain style of landscaping design. This category would contain parks, campuses, estates and recreation areas. The second category, the historic landscape or historic site, is a region that is associated with a significant historic event. Here, also battlefields and political locations would be attached. Historic vernacular landscapes are modified landscapes, where a certain tradition of land use or social behavior of certain groups of the society is practiced. This would address the largest parts of biosphere reserves, where traditional land use is an integral part of the preservation concept. Finally, ethnographic landscapes embody natural and cultural resources that an associated society or people defines as its heritage (e.g., sacred springs, mythological groups of trees, natural monuments).

Many landscape elements have a **special meaning to local people**. They are tightly connected to their mythology or history. Special trees or rocks (Externsteine in the Teutoburger Forest, Loreley at the slope of the Rhine Valley, Labyrinth of rocks at the Luisenburg in the Fichtelgebirge, etc.) attract people and let them identify strongly with these landscapes. Even some national parks have been created, that focus on such extraordinary landscape elements (e.g. the national parks "Elbsandsteingebirge" and "Jasmund" in Germany, see Figure 4.1-2). The integration of archaeological sites of high value into concepts of landscape management is a further approach, that adds archaeotopes to valuable biotopes and natural monuments (Behm 2000, Figure 7.8-5).

Figure 7.8-5: Landscapes can embody archeological and cultural sites being a heritage of the local people or even the mankind: The mysterious Bronze Age center of cult worship Stonehenge (England) (Photo: O. Bastian 1998)

The concept of historical landscapes, that consciously integrates the mythological importance of landscapes in peoples every days life, is considered a specific quality of protection in landscape planning (Hönes 1991). Recently, this approach has been extended to industrial landscapes (Kistemann 1998), that reached the conscience of the society mainly after the fall of East European socialist countries (Figure 7.8-6).

7.8.6 Conclusion

Human influence is all-pervasive in landscapes. It may not always be obvious, but it is rarely absent. If landscapes have evolved over long time periods together with human activities, these will be an integral and compulsory mechanism for the preservation of landscape functions and services. Human activities, such as landscape management and land use practices, affect and even create specific landscape elements. This is why the human factor can-

cannot be neglected in nature conservation. Mankind has contributed to the development of communities, ecosystems and landscape.

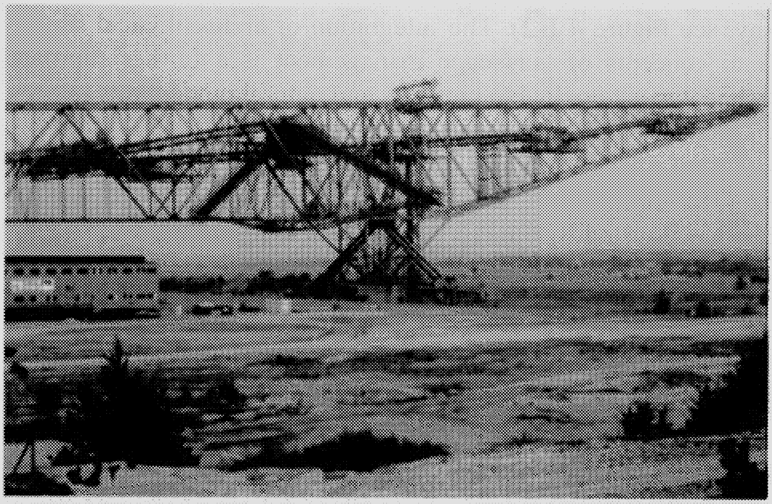


Figure 7.8-6: Recently, the protection of historical landscapes has been extended to interesting industrial areas: A conveyor bridge beat up in the closed lignite opencast mine "Bergheide" in the Lower Lusatian lignite mining region (Photo: O. Bastian 2001)

However, nowadays land use change is very rapid as a consequence of globalization and the rapid technical development. These changes will result in a loss not only of biodiversity, as most species cannot adapt as fast as necessary to the new environment, but also in a loss of land use types and techniques. This again, will change landscapes according to their aesthetic value and ecological function.

The conservation of certain historical aspects reaches a new dimension under this perspective. It is no longer a museum-like traditional and conservative approach (Behm 2001) but an important technique to support ecosystems and landscape elements with environmental conditions and disturbance regimes that respond to the species requirements, as most of our species have evolved in such systems. If we want to preserve our biotic resources, we have to manage landscapes not in a historical way, but integrate long-term evolved structures and elements.

7.9 Sustainable developmentof cities and urban regions

7.9.1 Introduction

Cities and urban regions are becoming more important at a global scale. At the beginning of the 21st century more than half of the global population lives in cities and urban areas (UNCHS 1996).

The **urbanization** processes differ considerably between different continents and countries depending on the particular economic status and the level of industrialization. In the "Third World", gigantic growth rates of large cities and metropolitan areas dominate the process combined with a considerable rural exodus, while North American, Western and Central European cities and towns are growing more slowly. Here, **suburbanization** (Figure 7.9-1) is the prevailing process, but it is much more dispersed in the U.S. than in Western and Central Europe (Prigge 1998). Germany is an example of an urbanized country: 33% of the population live on 5% of the total land area; 83 cities have more than 100,000 inhabitants (Mäding 1998).

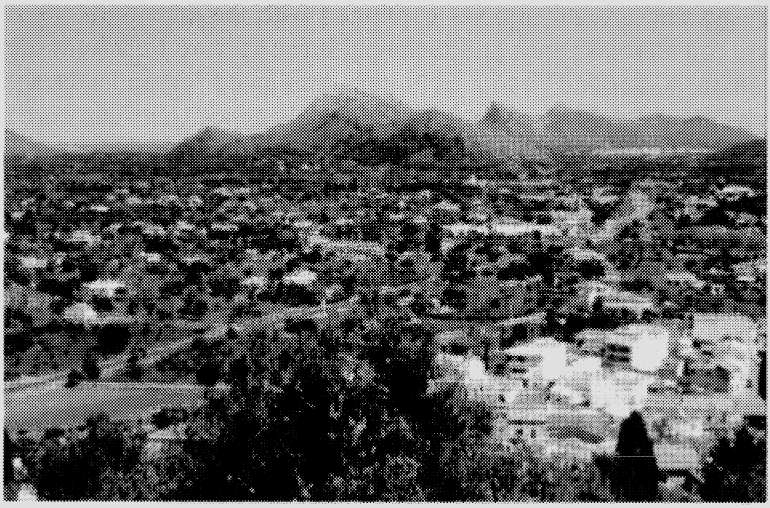


Figure 7.9-1: Suburbanization causes characteristic environmental loads, e.g. by an overdevelopment of the landscape for touristic purposes: Pollença (Isle of Mallorca, Spain) (Photo: O. Bastian 1999)

The following chapter describes Western and Central European cities and urban regions, in which the urbanization processes are very similar.

Facing the structural change from industrialized to service-oriented societies, current urban functions are being questioned. International finance transfers and modified price building procedures produce modified expectations in the regional division of labor (ARL 1998). Cities and urban regions can be split up into **winners and losers** (Wegener 1998). Metropolitan areas will grow more and faster than small and medium-sized cities and towns (European Commission 1994, Sassen 1996). The "winners" will be characterized by an increase of inhabitants, commercial zones, and environmental pollution. Generally, the "losers" will loose jobs and inhabitants, gain derelict areas and fallow fields, and environmental pollution will decrease because of the reduction of economic activities. The "winner-regions" of Western and Central Europe are growing comparatively slowly, but constantly; the trend to develop unimproved areas is unbroken. Urban regions grow even if their population is stable because of the increase of individual and commercial need for space. Where the distances between the single core cities are short, polycentric urban regions occur.

The relationship between the **core cities** and their surroundings (sometimes called "hinterland") is changing: the core cities serve considerably less as work places for the inhabitants living in the surrounding area, while the surroundings gain growing importance for housing, recreation and as economic zones and compensation areas. The "new centers" developing along motorways and around airports combined with the emergence of shopping centers, commercial zones and technical infrastructure transform the former rural urban "hinterland" into a technique-dominated "urban landscape" about it can be argued that there is a growing "equivalence" between core city and suburbs. In the emerging "city-landscape-continuum", "urban islands" alternate with "landscape islands"; the core city seems to disperse into the urban region (Sieverts 1998).

The growing extension of urban areas requires more individual and public transport leading to an increase of tangential **traffic** movements (Adam and Blach 1996); there is a vicious circle between the growth of urban regions and the increase of traffic (Locher et al. 1997).

Furthermore, suburbanization leads to characteristic **environmental loads**. From an environmental point of view, the networking of cities causes a fragmentation of landscapes, the transformation of habitats into different forms of land use and the loss of natural areas.

In conclusion: the (traditional) European town is dispersing. There are different reactions to the importance of this process from different special interest groups. Despite the increase in environmental pressures and structural problems, the urban style of dwelling with a high density of buildings is environmentally less damaging than rural settlements or suburbs with respect to the average land use per person.

7.9.2 Environmentally sustainable development

As there is no alternative to cities and urban regions, their sustainable development, especially with regard to the environment, is required. In Germany laws for regional and urban development have addressed this issue since 1998, when generic guidelines for sustainable regional and urban development became part of the regional and urban planning act; both contain also environmental aspects.

There have been many interpretations and definitions of the notion "sustainable development" since its initial conception in 1992, when the concept was outlined at the UNCED (United Nations Conference on Environment and Development, Rio de Janeiro 1992). There is no absolute definition of sustainable development; the concept is used as a guideline and interpreted differently both by disciplines and individuals (see Chapters 7.1.4 and 7.3.1).

In this chapter, the following **definition** is used: the general concept of **sustainable development** consists of an integrative treatment of ecological, economic, social, and cultural aspects of change in the long-term. The concept is so wide and complex, that it can be implemented only by discussion and co-operation of a variety of societal groups. **Environmentally sustainable development** is a subset of sustainable development that concentrates on the environmental aspects with their related procedures and institutional structures. Environmentally sustainable development is an ethical imperative; justice in the shared use of the environment, e.g. balancing environmental quality against resource use is one of its basic elements. It is more than environmental protection and environmental precautions.

Environmentally sustainable development comprises (Figure 7.9-2):

- the primary ecological aspects: it requires **consistency** that balances societal and economic use of resources against the carrying capacity of the environment,
- in environmental-economic terms: it seeks an increase in the **efficiency** of resource use,
- in social-ecological terms: it looks to change and replace lifestyles that waste resource with maintainable patterns of consumption and production, i.e. **sufficiency**.

Consistency, efficiency and sufficiency are three complementary principles that supplement each other; an environmentally sustainable development must meet the requirements of all three principles.

The concepts of sustainable development and of environmentally sustainable development have to be formulated and implemented by a variety of disciplines including spatial and environmental planning at regional, urban, and landscape levels.

Research for an environmentally sustainable development can be classified by the dimensions it addresses:

- in a two-dimensional or spatial view: space management,
- in a three-dimensional or "functional" view: resource management,
- in a four-dimensional view: spatio-temporal management and
- in a "five-dimensional" view: new culture of planning.

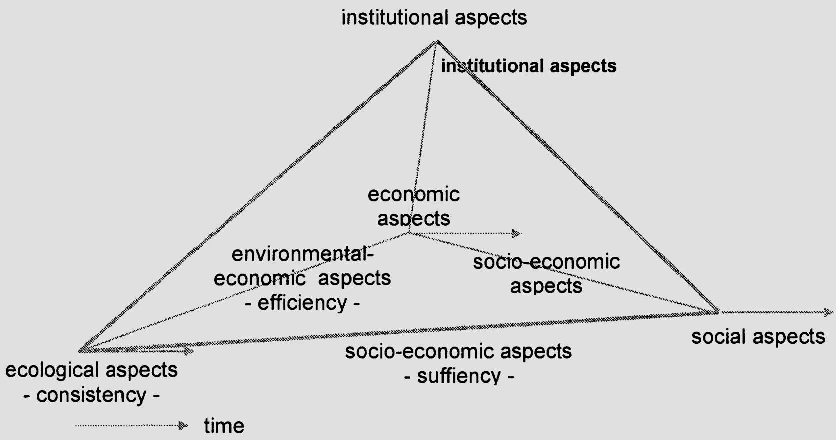


Figure 7.9-2: Elements of an environmentally sustainable development

7.9.3 Space management

Effective control of land use, in order to minimize environmental pressures and maintain the environmental carrying capacity (see Chapter 5.1.1), requires space management in cities and urban areas. Space management is the data-lead control of the patterns of land use and land(scape) functions.

Aims of **quantitative space management** include:

- density of buildings and mixture of uses,
- re-use and recycling of building areas as well as commercial and industrial wastelands, and
- compensation for the land utilization for housing, industrial, commercial, and traffic areas.

Qualitative space management aims at the careful, environmentally sound use of surface and soil. Not only does the area under different use need to be taken into account, but also its functionality and the drivers for its use.

There are already several **approaches** to space management in regional and urban planning. Spatial and environmental planning dedicates spaces and areas and places constraints on land use. Regional plans control land use by defining priority, provisory, and suitability areas. Large cities, such as Berlin and Stuttgart, attempt space management in their surroundings, which includes open space in "Regional Parks". Furthermore, the German compensation law implements aspects of space management, but, only selected parts.

There is a **requirement for research and development,** to extend the existing approaches to space management at regional and local scales in the following aspects:

- co-operative development of **guidelines for land use** (see Chapters 7.2 and 7.12). The guidelines and aims should meet and make more explicit the basic principles of environmentally sustainable development: consistency, efficiency, and sufficiency. They should be produced through a co-operative process by discussion of all relevant societal groups,
- investigation of **environmental, health and nature protection** aspects by environmental planning,
- development of open space networks and habitat systems, which are useful partly for nature protection and partly for human recreation purposes in all cities and urban regions,
- wider application of the landscape framework plan in regional planning and regional development: landscape planning at the regional level is often concentrated on nature and habitat protection and the demands for recreation; the air/climate, soil and (ground-) water are often neglected,
- use of economic instruments to control land use e.g. financial incentives, taxes and contracts with private investors or actors, and
- development of a land register: detailed information including the density and distribution of building structures and their technical infrastructure.

7.9.4 Resource management

There is no doubt, that the extent of resource use in industrial countries, and especially in their urban regions, has to be reduced for environmental and financial reasons. Resource management is the data-lead control of the use of resources.

The aim of **quantitative resource management** is to reduce the use and flux of material and energy and minimize waste (water, materials and gases). The potential risks of posed by materials and energy (**qualitative resource management**) also needs to be taken into account.

Details of urban-regional resource management are still unclear, but the general **need for development** can be characterized as follows (similar to space management):

- co-operative identification of guidelines for sustainable resource management: the carrying capacity, the efficiency of resource use and the sufficiency in lifestyles serve as basic principles for the use of resources by production, housing and consumption,
- development of an equivalent data-bases on material and energy fluxes in and between urban regions, and
- involvement of the resource user.

The development of an urban-regional resource management system faces considerable resistance; therefore its implementation will be difficult. The expansion of functional networks of cities and urban regions; European integration and globalization is leading to global transfer of goods between cities and urban regions. Material and energy fluxes are linked to an extent that requires an investigation to identify which products and materials can be subject to an urban-regional resource management in a meaningful way.

7.9.5 Spatio-temporal management

The recent societal change is connected with an acceleration of economic and societal processes. The speeding up and the ignorance of natural rhythms and peculiar time phases is producing a high-speed "non-stop-society", where time patterns become monotonous and steady. But the speeding up of economic processes and the "condensation of time" leads to irreversible environmental impacts and resource depletions. The (mis)use of fossil resources can be interpreted as a disproportionate use of the time that is accumulated within them, and therefore as a "theft of time" (Held 1998).

Between spatial and temporal structures exist dense but to date hardly recognized linkages; the changes with regard to time (speeding-up, just-in-time-production, etc.) have a major influence on spatial structures (Wolf and Scholz 1999). In urban regions, the speeding up is visible in the expansion of high-speed roads, rails, and telecommunication networks ("data highways"). They lead to a lower resistance against traffic or a "shrinkage of space" (Henckel 1997).

The time-scale which is relevant to environmental precautions and long-term stability, and which underlies the sustainable development concept, is not the same as the short- to mid term horizons in policy, economy and planning However, trying to take into consideration the long-term perspective, by predicting long-term societal developments, causes considerable epistemological, conceptual and methodological problems. Instead of ignoring the problem, we should develop a conceptual framework to predicted guide future developments.

In order to find long-term perspectives for the development processes of a city or urban region that will allow us to assess the changes in circumstances and situations we must develop a "policy of time". A "Commission for the Future" or a similar institution should analyze the general interrelationships between societal, economic, environmental and cultural development processes and propose alternatives for future development, change and eventual control measures. These proposals should be discussed in democratically legitimized institutions, such as urban or regional councils and with the general public.

"Spatio-temporal planning" has to take into consideration the relationship between societal time and spatial use so that it can optimize both mutually in all planning tasks. Time has to be taken into account in all phases of planning. A "mapping of the spatio-temporal uses" should document uses and their intensity, dependent on where and when they happen so that both "under-use" and "over-use" can be identified. The analysis and documentation of use intensities will deliver the necessary, basic information to steer towards a balance of use intensities.

To date, it is an unanswered question, whether and how long-term societal development and structural changes can be predicted at least relatively exactly; the spectrum of possible development paths and the uncertainties in knowledge grow exponentially with the time scale considered (see Chapter 4.3).

7.9.6 New planning culture

As economic processes speed up, the authorities have to act and react faster in the planning process. As more people participate in the planning process with the aim of safeguarding their interests, both the process and the planning culture are changing. The importance of formal plans is being superceded by negotiations and bargaining between the administrations and investors. Private actors, such as environmental groups or regional and Local Agenda 21 initiatives, are gaining weight in the planning process. As investors and private actors restrict their interest to certain projects – and will only finance specific projects – planning has become "project-oriented". The former planning processes are changing to management processes, and this shift causes a new planning culture:

- **strategic orientation of planning** in order to facilitate a democratic control of negotiation processes and results. Planning processes need "crash barriers", which can serve as a framework and set limits for negotiations. These "crash barriers" are a strategic orientation of planning at all political levels,

- **horizontal co-operation and co-ordination** in order to avoid divergences between political and planning activities as well as inefficacy and inefficiency,
- **vertical co-operation** between the different political levels (feedback-principle), and
- **evaluation and control with sustainability indicators** whether the economic, social, environmental and cultural development move in the expected direction.

7.9.7 Conclusions

Environmentally sustainable development of cities and urban areas leads to considerable challenges for spatial and environmental planning. Both planning forms are losing importance given the "withdrawal of the state" facing the growing influence of private, especially economic, actors. The shift in importance from formal state-planning to informal private-public management requires from both planning systems an assessment of their efficacy and an improvement and an adjustment of their organizational structures and their methods. As the relationship between spatial planning and landscape planning is conflict-ridden, with the environmental aspects often being disregarded in spatial planning, better coordination is needed. Improved coordination is also required between the various forms of environmental planning (e.g. water management plans, climate protection and waste management concepts).

There is a need for further development of environmental planning – not only in urban areas –in order to improve:

- evaluation of the need of protection of every urban space with respect to the environment (water, soil, air, climate, flora and fauna), human health and nature protection,
- (further) development of environmental quality target systems, which comprise also targets in order to meet the principles of consistency, efficiency and sufficiency (see Chapter 7.2), and
- environmental impact assessment of plans: prognosis and assessment of environmental and human health impacts of planning purposes.

Developing space, resource and spatio-temporal management and a new process-oriented and co-operative planning culture requires interdisciplinary and transdisciplinary work and research (see Chapter 1.3). The formal instruments have to be complemented by new participatory approaches using strategic (see Chapter 7.12) as well as economic approaches. The flexibilization of planning and the growing influence of private actors require a democratic legitimization of decisions making. A strategic orientation of planning, that encompasses a strategy for sustainability, which aims at all political levels can provide guidelines to decisions and help to legitimize the results of negotiations. Additionally, sustainability indicators are useful in order to evaluate socio-economic and environmental developments, whether they are sustainable or not, i.e. whether they meet the principles of consistency, efficiency and sufficiency.

7.10 Urban Ecology

7.10.1 Introduction

The new millennium will be a millennium of very rapid urbanization (see Chapter 7.9.1, Figure 7.10-1). Already, the world's largest cities have reached more than 20 million inhabitants, and there is no limit to the size of a city. Cities are clustering, and, together with their surroundings, they are developing more and more the character of extended large urban landscapes.

Today, residential areas and roads cover 12.7% of the total land area of Germany. The demands for space for urban use is growing, not only in Germany. This is causing a progressive transformation from previously agricultural/forested landscapes into urban landscapes, or a constant rebuilding of the existing urban landscape. City landscapes are concentrated living spaces and the most denaturalized ecosystems of the new century (Figure 7.10-2).

Figure 7.10-1: In 2025, 60% of the world's population will be living in urban areas: The city of Copenhagen (Denmark) (Photo: O. Bastian 1991)

Figure 7.10-2: The high population density in the big cities leads to severe ecological problems, e.g. surface sealing and habitat loss: Skyscrapers of Yokohama (Japan) (Photo: O. Bastian 1993)

For a long time, these extensive manifestations have not been restricted to industrialized nations, but have been increasing especially in developing countries in significance, population, and area more and more. The population density and expanse of land in urban landscapes of the First and Third World countries vary greatly. The urban landscapes of Asian countries are the most compact, and those of North America and Australian are the most spacious and expansive. Despite the differences, all urban landscapes are indicating a tendency to reduce density. By externalizing urban functions from the city core into a diffuse, transition area between urban and agricultural areas, surrounding agricultural/forested landscapes have been integrated into the urban areas. The cause of this process and of the growth of urban landscapes is the availability of cheap automobile transportation and the provision and expansion of the required road infrastructure. Modern urban development without this prerequisite is unimaginable (Sieverts 1998, Figure 7.10-3).

7.10.2 New discipline of science: Urban ecology

The study of cities and urban landscapes from an ecological perspective is a new field of research. The reciprocal dependencies and relationships between organisms and their environment were initially contrary to biological research. Plant and animal communities, with their respective favored and disfavored environments, and their habitat (biotope) were being researched.

Along these lines, Central European research developed the term "Stadtökologie" in the 1960s. The American term "urban ecology" has been in use since the 1920s, but its roots are exclusively sociological. "Urban ecology" as urban sociology describes the relationship between city and society. Research of organisms and their environment in North America are summarized as "urban wildlife". However, differing positions in the field of urban ecology exist even in German and European scientific literature.

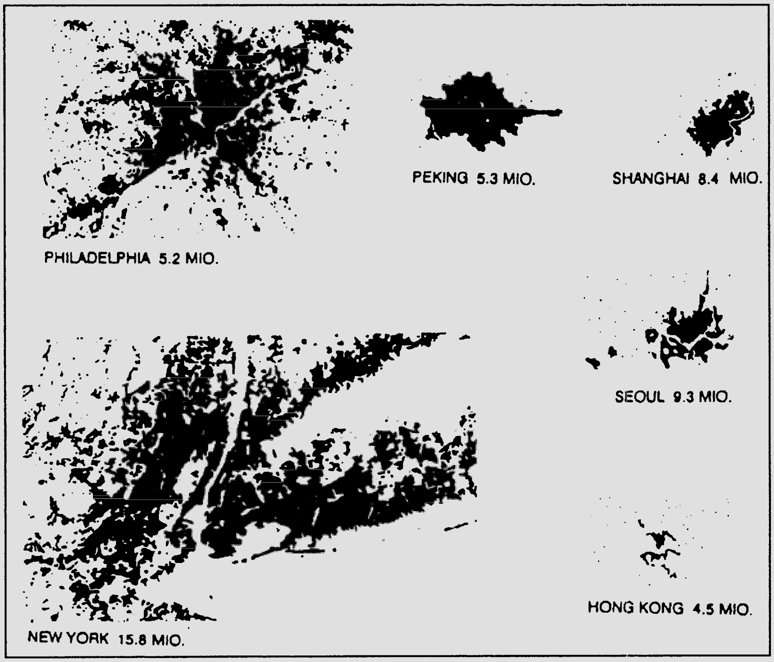


Figure 7.10-3: A contrast of housing developments (number of inhabitants and required area) (from Sieverts 1998)

Biologists claim urban ecology as a biological science: "Urban ecology in its most precise sense is the only branch of ecology encompassing urban plant and animal communities, biotopes, ecosystems, the organisms and habitat requirements of those ecosystems, as well as structure, function, and history of urban ecosystems" (Wittig and Sukopp 1998).

Since urban ecology – often despite its biological roots – came into being primarily as an applied science, the overwhelming, research-driving question was: How can the human-ecosystem-complex city be designed to be more people-friendly? "Urban ecology in the broadest sense is an integrated field of several sciences from different areas and from planning with the goal of an improvement of (human – author's addition) conditions and a long-term, environmentally-sustainable urban development." (Wittig and Sukopp 1998).

Each point of view is supported by a large number of representatives and scientific works, of which Wittig and Sukopp (1998) provide a good overview.

7.10.3 Urban ecology as urban-landscape-applied landscape ecology

"The city" as a political entity or as a habitat-holding body is not the primary interest in research in landscape ecology. Here, the focus of study is the urban landscape itself.

Urban landscapes do not consist of a single, independent ecosystem, but rather is a complex of many different ecosystems, which have symbiotic relationships to each other and create complementary immediate surroundings. Physical differences within an urban landscape make them extremely distinct, and their functional needs are distinguished from dominant agricultural/forested landscapes by the type and intensity (land use contrast), size, distribution, and amount of nearby intensively used areas (energy and material input, landscape structure, landscape mosaic).

Both the observation of cities with their surrounding, autonomous landscapes influenced by the built urban environment and the study of these landscapes with available landscape ecology research instruments open up new perspectives into understanding relationships within ecosystems and targeted planning and development.

"**Urban ecology** is the application of landscape ecology. It provides the basis for a landscape ecology model of urban ecology and assumes a combined effect of geo-ecological factors among others. Natural-born and human-influenced factors have also been studied and placed in their political, social, and economical context, resulting in a very sophisticated model of urban ecology (due to its complexity). Currently, this model exists only as partial models, which are quantifiable. The ecosystem models are regarded as subsystems, which are categorized under a standard function scheme according to their module principle. This theory has not been discussed by practitioner until just recently" (Leser 1997, Figure 7.10-4).

The **urban ecosystem** is a functional unit of a section of the geobiosphere. The combined effect of the natural-born (but no longer natural), abiotic (including human), and biotic factors is self-regulating, but exclusively urban-industrially human-driven. The ecosystem can be described as a dynamically balanced system, always open to material and energetic influences. It requires, however, constant energy input from various sources to remain functional. Determining regulators for the functions of the urban ecosystem are the economic, political, and social relationships as "uses" in their broadest sense. They can form partially independent subsystems in the urban ecosystem and simultaneously represent the urban ecosystem as fundamental parts (Leser 1997).

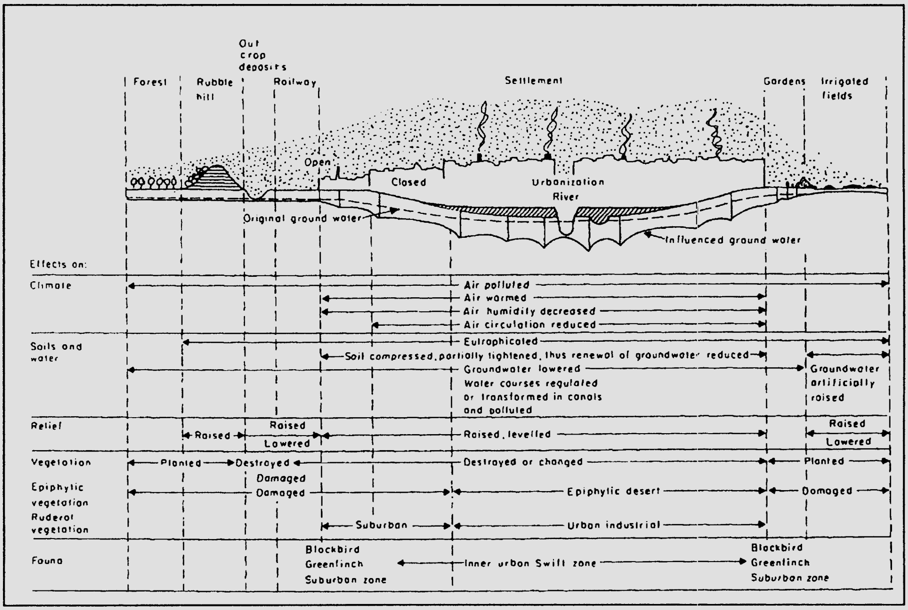
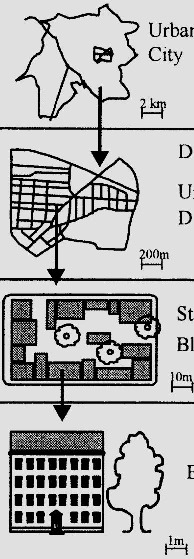


Figure 7.10-4: Model of the urban ecosystem (Sukopp 1973, 1998)

The urban ecosystem can be modeled at different function levels by considering the dimensions (subtopological, topological, chorological), whereby differences in scale and content can allow one case to be more complexly worked and the next less complexly worked, without losing the integral base (Figure 7.10-5). The landscape ecology approach often reaches far into the area of human systems and involves causal research in urban problems. Müller (1979) describes, for example, the "urban ecosystems" as "biotopes of human activity".

7.10.4 Land use as a methodical base of analysis of urban landscapes

In settled areas, primarily the utilization characterizes the pattern of expansion of organism types. Therefore, the foundation of the protection of natural areas in cities is to systematically record the most important types of **land use** in their existing vegetated state and a description of its ecological requirements to exist. The end product will reveal in which scales individual uses account for certain characteristics of a species in settled areas. It will also reveal which land uses resist species deficiency and under which conditions are measures towards "renaturalization" necessary (Sukopp et al. 1980).



Scale Level	Administrative	Planning Level	Landscape Dimension	Research Topic Urban Climate
	Urban Region/ City	Land Use Plan	Urban Eco-System meso-choric/ macro-chorical	Joint Climatope
	District Urban District	Land Use Plan	Subsystem nano-chorical	Climatope of Concentrated Building
	Statistical Block	Building Plan	Landscape Structure topical	Court Yard Climate
	Building	Building Plan	Landscape Element topic/subtopical	Building Climate Tree Climate

Figure 7.10-5: Model of the urban ecosystem, taking partial systems and dimension levels into account

Land use is the fundamental human process of acquiring space. Individual, group specific, or social, this process calls for the demand for technical and natural conditions of the human environment. Land use is not a state of being, but rather a process. If the process is constantly reproduced, a delicate balance takes shape that depicts itself as **land cover**. Between land use and land cover exist close, but no explicit relationships.

The perceived value for nature in cities that grew in the 1970s with the realization of the extent of loss to that point led to the demand for practical and manageable environmental protection in cities. A methodical instrument was required for this purpose. One of these was available in the "Mapping of protection-worthy biotopes in Bavaria" (Kaule 1975), which was distributed to almost all other German states in a similar form in the following ten years.

Examples of species protection and landscape as well as functions of use and protection were the focus. For urban nature conservation, land use structures were interpreted as general starting point. The types of use that are bound to humans and their lifestyles also offered a new understanding of nature protection under urban conditions. Nature protection in the city should not nor is supposed to take on the primary role of species protection for threatened plants and animals, as it normally assumes in the open landscape. Its task involves to a much greater extent the deliberate preservation of living things and communities due to the importance of residents' direct contact with natural environmental elements (Sukopp et al. 1980, Sukopp and Weiler 1986).

Because they recorded the structures of human acquisition of space, any kind of utilization (land use types) were predestined to serve the foundation of ecological physical categorization and nature protection strategies in the human habitat of the city. In the 1980s, nature protection oriented **habitat maps** in cities were often reduced to species and habitat protection. Often following a species distribution map was a register of plant and animal species only oriented to species protection, since primarily biologists in the field were and are familiar with the problems.

With initial programs for the surface-covering mapping of settled areas in 1986, the land use-related recording of biotopes became the standard method (AG Methodik der Biotopkartierung im besiedelten Bereich 1986 and 1993).

In the 1980s the issue of the illustration and organization of research results from differing disciplines within the urban realm came more strongly to the forefront. Landscape ecology which had up to that point strictly let cities go unnoticed as landscape parts, attempted to pose the challenge. The objective was to illustrate a clearer physical and special perception from the givens in the urban landscape ecology. This was and is a project landscape ecology had been doing for a long time outside of the urban realm (Neef 1963, Neef et al. 1961). Especially in the 1980s, work in urban landscape ecology increased (Billwitz 1977, Breuste 1985, 1989, Haase and Richter 1980, Hülbusch 1982, Kaerkes 1985, Richter 1984, Schönfelder 1988).

It became known, in geographical landscape research that the social function of areas is not necessarily of pressing importance for physical landscape organization. Organization depends much more on the "process of landscape influence and change" (Schrader 1985 = land use). "For assessments of the ecology of settled areas, the economic functions of land use types of settled areas do not appear to be meaningful, but rather the degree to which the landscape's natural material and energy balance are characterized" (Schrader 1985). This is reflected in a distinct point of view, usually land use based, but in this instance originating from landscape ecology. According to types of use, ecological units of space, urban landscape units, and/or urban structure units were developed into physiognomically uniform characteristics (Breuste 1985, 1989, Duhme and Lecke 1986, Duhme and Pauleit 1992, Leykauf et al. 1989, Table 7.10-1).

Table 7.10-1: Structural and landscape ecology based physical organization of the city of Leipzig.

• residential land and land of mixed use - city center - detached curb-close apartment buildings with built-up courtyard (1870-WW I) - terraced curb-close apartment buildings with built-up courtyard (1870-WW I) - detached curb-close apartment buildings with built-up courtyard (1900-WW II) - terraced curb-close apartment buildings with built-up courtyard (1900-WW II) - free standing blocks of flats in rows (since WW I) - large new prefabricated housing estates (since 1960) - detached and semi-detached houses - villas - former village centers	
• industrial areas - new, medium density industrial and commercial areas - old, high density industrial and commercial areas	• recreational areas - parks and green spaces - allotment - cemeteries - sports fields, playgrounds
• special estates - large public facilities - shopping centers - public utilities and waste management plants	• infrastructural facilities • agricultural areas • woodlands • river and standing water • waste ground and changing areas • quarries, pits, mines and related facilities

7.10.5 Natural science approaches to the complex urban ecosystem

The classic topic of approaches to the study of urban ecosystems result from the scientific field of urban climate/air cleanliness; soil and water management; flora, vegetation, and fauna.

Research in urban **climate** is one of the oldest approaches to the ecological system of a city. By 1833, the book entitled "Climate of London" by the chemist Howard was already in its third edition. The advanced and technologically possible meteorological observations quickly led to the realization of the peculiarities and the study of the causes of these peculiarities. Mobile survey vehicles and thematic maps enabled physical evidence of the thermal characteristics to be collected in the 20th century. Human-bioclimatological studies in the 1930s connected this century to prior works and affected city development and planning. The subject "urban climate" was born as a scientific discipline with the publication of the textbook "Das Stadtklima" ("The Urban Climate") in 1937, and further developed in Landberg's "The Urban Climate" in 1981. The discipline illustrates a broad field of analytical research with applied-planning aspects as tools in the decision-making process of city development (Kuttler 1998).

Not until the 1970s did urban **soil** research develop from the careful beginnings of empirical application of classic soil analyses into the various anthropogenic substrates in cities. Geological formations and their ecological characteristics were studied and assessed. Sealed surfaces and their physical qualities began to be researched, since these ground surfaces were continually increasing in size in the urban landscape (climate functions and water management functions). Soil classifications were developed to produce comparisons between results. The first urban soil maps came out (Environmental atlas of Berlin 1993). Especially the land use's influence on soil characteristics was distinctly studied. The problem of pollutants (heavy metals, in particular) in urban soils increased in importance in research, and recently, questions regarding urban soil management and soil preservation have increasingly come into light. While research predominantly took place in Central Europe (especially Germany) in the 1970s and 80s, the research field is currently world-wide.

A noticeable increase in the realization of the balance and perception of **water** management in the urban ecosystem only took place in the last 20 years. Questions of groundwater replenishment and the load onto the ground water and infiltrated water gain significance for city and regional planning.

Berlin was the first location of a biological study of an entire city area (Scholz 1956). The first detailed analysis of the flora of a metropolis was in 1974 and also in Berlin (Kunick 1978). In the meantime, a variety of European cities were well studied for their **flora and vegetation**. Exemplary works from other continents also came about. The first ecological observations began in the 1970s (Sukopp 1973). Meanwhile, queries into the bioindication based on plants of air quality, thermal distinctions, nature protection, and urban biotope mapping. Studies of the spread of plant and plant communities and of the composition of flora required the recording of existing conditions on a small scale. Recently, protection and use of flora and vegetation in cities have not only stood at the center of interest of researchers, but also of the applied planners.

Urban **fauna** ecology involves systematic investigation and description of occurrences, distribution, and changes in individual subjects along with their conditions and causes. Besides the characteristics of the urban fauna, questions about the shaping of the city population as metapopulations, the role of the resulting culture, its relation to use and biotope and species protection are also handled (Erz and Klausnitzer 1998).

7.10.6 Problems, perspectives and planning-related application

Despite the various steps to the current state of research in urban landscapes and ecosystems and a vast diversity of existing individual findings, a common theoretical basis and an agreed upon methodical instrument was lacking. The objectives of the individual disciplines were often specific to a certain discipline and not always reported among the urban landscapes research field. Nevertheless, the urban ecology research field as applied landscape ecology gained importance due perhaps to urban planning's increasing need for applicable ecological findings and due to the constant pressure in expanding cities.

The practical demands strongly influence the direction the field presently takes. Included in this are urban nature protection (from increasing denaturalization), remote sensing methods (necessary for effective multitemporal monitoring of environmental conditions in face of change of use dynamics), applications of GIS-technologies (for data administration and for modeling of physical space and exposing relationships between partial systems), studies on the ecological functions of types of sealed surfaces and their ability to be altered (from increasing hydrological and urban climate problems), modeling of water management of city sections (required from increasing shortages and purification problems, urban hydrology), and much more.

It is becoming more and more clear that a variety of socio-economic disciplines must be pulled in to help find explanations for the roots and effects of ecological conditions. Sociology, economics, planning, and community political science play an increasingly important role as factors of development. Of particular mention are further changes in the structure of urban landscapes caused by suburbanization, more specifically its dynamically changing automobile-oriented infrastructure.

The surrounding issues are the organization and proximity of other uses in urban landscapes, the environmental sustainability (see Chapter 7.9) and acceptance of uses, and the value of different types of natural areas and of urban landscapes of limited space. The preservation and development of the quality of life in urban landscapes in the face of economically and socially caused transformation is becoming the crux of urban system complexes. The urban ecology as applied landscape ecology calls for extensive study on the functioning of components and ecosystems of urban landscapes, and for the contribution of problem-related application of these findings. The major challenge is the effect on the shape of tomorrow's city.

7.11 Restoration Ecology

7.11.1 Introduction

The appreciation that the establishment of nature reserves was not able to stop the dramatic loss of biotopes and its accompanied loss of species has lead to new paradigms in nature conservation. The mainly defensive strategies are being completed or replaced by more affirmative ones, aiming to enlarge, connect and restore sites of high natural values, also in landscapes and areas that have suffered from various forms of destruction. During the last decade the number of projects involving ecological restoration has multiplied, often supported by new legal frameworks (Bruns and Gilcher 1995). Restoration has advanced to the leading issue of nature conservation – or more appropriately nature development – and the potential role for restoration ecology is enormous (Edwards et al. 1997).

In this chapter we give an overview on the current aims and definitions and on the most important concepts, strategies and techniques of ecological restoration. We focus mainly on Central European approaches.

7.11.2 Terms, topics and aims

Restoration (German: Renaturierung) by its strictest definition implies a return to a former original state (Webster's New Collegiate Dictionary 1983). Ecological restoration aims to return ecosystems or biotopes to more natural states providing new living space for endangered, rare or typical organisms, and repelling organisms populating areas highly influenced by human activities (Klötzli 1991a). The Society for Ecological Restoration (SER 1997 in Brülisauer and Klötzli 1998) defines ecological restoration as "the intentional alteration of a site to establish a defined indigenous, historic ecosystem. The goal of this process is to emulate the structure, functioning, diversity, and dynamics of the specified ecosystem". As a complete return to predisturbance conditions is hardly ever possible, restoration usually means "returning an ecosystem to a close approximation of its condition prior to disturbance" (National Research Council 1992). However, sometimes restoration in the strict sense is not a practical option. Possible reasons for a **partial restoration** (Jordan et al. 1987) are:

- we do not know how to do it properly,
- it will take too long,
- the environmental conditions have fundamentally changed,

- the targeted ecosystem is not precisely defined, and
- the historical state of an ecosystem is not known.

Although most definitions of restoration refer to former, more natural and less "disturbed" states of an ecosystem, it is important to recognize that in many cases it is aimed to restore

- ecosystems which **need regular disturbance** by human actions, e.g. species rich meadows by mowing or grazing, and
- ecosystems with new properties or even with **no historical reference** (Lewis 1990).

More general and suitable criteria for the essence of ecological restoration therefore are:

- site adaptation,
- enhancement of self sustaining processes (including human ones, such as economic aspects in a long term view), and
- enhancement of locally typical and adapted biodiversity.

A list of related terms to restoration in the field of conservation and restoration biology is used in literature. The most important are defined as follows:

Rehabilitation (German: Regeneration) is a broad term that may be used to refer to any attempt to restore elements of structure or function of an ecological system, without necessarily attempting complete restoration, for example replanting of sites to prevent erosion (Bradshaw 1997, Meffe and Carrol 1994). Rehabilitation is sometimes used informally as a general term for the re-creation of unspecified wildlife interest (Wheeler 1995). **Reclamation** refers to rehabilitative work carried out on the most severely degraded sites without aiming full restoration (Schaller and Sutton 1978). In Britain and North America, this term is used by many practitioners in the sense of "making land fit for cultivation" (Bradshaw 1997). **Ecological recovery** means the self-driven succession letting the system return to previous state on its own (Brülisauer and Klötzli 1998). **Recreation** attempts to reconstruct an ecosystem, wholesale, on a site so severely disturbed that a restoration is not possible (Meffe and Carrol 1994) or the new creation e.g. as a substitute for a destroyed biotope on another place on a site where this type of biotope never existed before. **Recultivation** means the regeneration of ecosystems for cultivation purposes.

7.11.3 History and objects of restoration and restoration ecology

Since the emergence of restoration ecology in the 1970s, it has developed into an important branch of ecological research as well as a profession (Edwards et al. 1997). Until the beginning of the 1990s, the applied branch of restoration ecology in Central Europe focused on the one hand on the re-creation of more or less natural habitats on special sites, mainly on moorlands and heaths (bibliography in Klötzli 1991b, Pfadenhauer and Klötzli 1996, Figure 7.11-1), and on the other hand increasingly on secondary sites such as old coal mines (Smith and Bradshaw 1979, Figure 7.11-2), road slopes (Stottele 1995), running waters (Brülisauer and Klötzli 1998) or degraded ski slopes (Schütz 1988). In particular, in North America, restoration ecology was used to describe the production of small-scale copies of different vegetation types (Jordan et al. 1995).

Figure 7.11-1: In Lower Saxony (Germany), large fens were exploited for peat. Now, many of them shall be rehabilitated for wildlife, a full restoration in a short run, however, is impossible (Photo: O. Bastian 2001)

At the end of the 1980s, the creation of hedges marked the first step of the applied restoration ecology from areas of special interest into the "normal **(agri)cultural landscape**" (Benjes 1991) – an ecosystem that was neglected or even "given up" both by the nature-protection and the ecological research. Since the beginning of the 1990s, this new focus on the (agri)cultural landscape has been supported by direct payments for farmers in Europe for particular ecological performances, like providing and cultivating habitats rich in species. Where these habitats were missing, they had to be created.

Switzerland is a leading example with large areas of wildflower strips (Schaffner et al. 2000), species rich hay meadows (Bosshard 2000a) and other habitats that have been restored (e.g. Nentwig 2000, Pfadenhauer 1990) while other European countries can show similar, if lesser, restoration. The latest new challenge for the restoration ecology arises from the structural change leading to agricultural retreat; new solutions are required to recreate new landscapes, e.g. by extensive pasturing or reforestation.

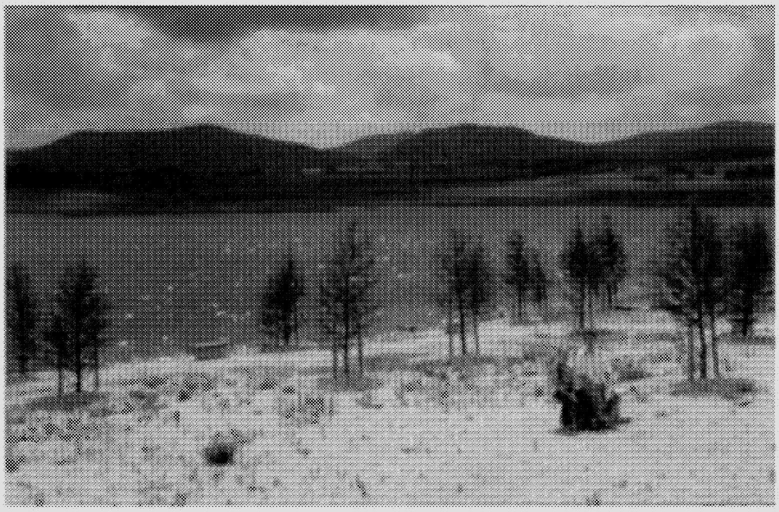


Figure 7.11-2: After opencast lignite mining in the Lusatian region artificial lakes are arising by the rising groundwater table. Thus, new multifunctional landscapes can be developed: The former opencast mine Olbersdorf near Zittau (Saxony, Germany) (Photo: O. Bastian 1999)

In situations where intensive agricultural production was present over a longer period, most of the targetted species disappeared from the seed bank of whole areas (Bosshard 1999) and must be re-introduced – mostly with commercial seed mixtures. A main bottleneck for many restoration projects today is the availability of ecologically adapted propagules of regional provenance (Keller and Kollmann 2000, Maunder 1992) – be it seeds or whole plants (Brown 1989). Meanwhile, in Switzerland, as in parts of Germany and England, many nursery gardens and seed firms have responded to the demand for native, adapted plant eco-types.

In many landscapes **river ecosystems** play a key role in maintaining regional biodiversity. They provide a rich variety of habitats for many rare and endangered species and carry out important hydrological functions for whole watersheds including ground water recharge. They can also act as buffer strips preventing non-point source pollution by agro-chemicals. In this way they contribute to an improvement of running water quality. In Europe, several large-scale river restoration projects have been realized, or are in planning (Schiemer 1999), but also small-scale restorations are of great importance and implemented, e.g. in the canton of Zurich (CH) about 30 km between 1989 and 1998.

The development of restoration ecology described so far shows how its meaning and range has strongly expanded (Bosshard 1999). Correspondingly, there is a need for new concepts and solutions. Instead of acres and hectares today often hundreds or thousands of hectares are of concern, and instead of special, mainly meso- or oligotrophic sites and special habitats **solutions for whole landscapes** with the whole range of mainly eutrophic soils have to be found. And more and more practitioners like farmers, or NGO's and public services in communities become important initiators and workers in restoration projects. And, last but not least, the restoration projects have to respect the demand for sustainable solutions also in economic and socio-cultural regard (see Chapter 7.12).

7.11.4 Scientific knowledge and concepts of restoration

To be successful, restoration depends on detailed knowledge of (1) structures, (2) functions and (3) interrelations within and between ecological systems. Since Bradshaw (1987) restoration ecology has often been defined as "the acid test for ecological theories".

Ecosystem theories have developed from two distinct sets of assumptions. Classically, ecosystems are thought to reach stability through succession, after which processes are in dynamic equilibrium. This model suggests that systems are closed and self-regulating, that, during succession, ecosystems will increasingly control the flow of matter and energy. Processes or events that move the ecosystem away from this equilibrium are considered **disturbances** (see Chapter 7.8). Disturbances are thought, under the classical view, to be exceptional. In contrast, the contemporary paradigm assumes that ecosystems are open, can be regulated by external processes, and are subject to natural disturbances. They may have multiple and probabilistic successional stages (Gassmann et al. 2000), which at some cases may lead to multiple equilibria, while in other cases may fail to reach an **equilibrium**, depending on the interrelation between too many surrounding conditions. Ecological theory has shifted to this contemporary view because both empirical explorations of natural systems, as well as the prominent failure of management based on older equilibrial assumptions, showed its limitations (Parker and Pickett 1997).

Implicit in the contemporary approach to ecosystem dynamics is a requirement to understand process and context: **Processes** refer to biotic and abiotic interactions (internal processes) and inputs or disturbances (external processes) that influence dynamics. Any process may influence a number of ecosystem characteristics simultaneously. If restoration is focused on re-establishing functioning and self-sustaining systems, then recapturing the dynamics of systems may be dependent on ensuring that appropriate processes are returned or maintained.

Context contains both spatial and temporal aspects: **Spatial context** refers to the geographic connections of the site of interest with the surrounding landscape. For example, differences in continuity of vegetation strongly influence the movement and propagation of a number of processes such as invading species, gene flow, pathogens, etc. **Temporal context:** relates to the result of a historically unique combination of processes that have operated on that ecosystem, which we refer to as contingency. This crucial feature of complex systems is often neglected. Egler (1954) elaborated the concept of "Initial Floristic Composition" (IFC) which describes the biotic contingency, this has been expanded with empirical data by workers such as Fischer (1987). The concept influenced several recently applied restoration research projects (Bosshard 1999, Patzelt and Pfadenhauer 1998). The IFC-concept refers to the idea that plants established from an earlier point in time – maybe by chance or accidental climate – have an important or even decisive influence on the future development of the ecosystem.

Today there is a consensus about the stochastic and dynamic character of restoration processes. It is generally accepted that the results never can be predicted and planned in precise detail (Gassmann et al. 2000, Klötzli 1987). Thus, to a certain extent the development of a restored ecosystem has to be monitored permanently, and deviations of the targeted way have to be corrected or adjusted by individual measures based on the knowledge of restoration ecology (Table 7.11-1).

7.11.5 Strategies and measures of restoration

Within the manifold factors influencing the development and success of restoration, the following have a most decisive effect and, at the same time, have been objective of many studies (for an overview see e.g. Bakker and Berendse 1999, Bosshard 1999):

- nutrient availability and their sustainable input: limitation of N, K or P in wetlands,
- light availability,
- water regime,
- role of the actual vegetation including its seed bank,
- invading possibilities for plant and animal species,
- size of the area, and
- disturbances.

Most of these key factors can be manipulated in the frame of restoration projects. A (incomplete) systematic overview about the great range of available techniques and the respective suitability is given in Table 7.11-1.

Table 7.11-1: Strategies and measures of restoration – a provisional checklist. The decision about the suitable combination of measures depends on the goals, the particular site conditions and the project frame (finances, acceptance). Only selected references, containing additional literature

measures	decisive factors, particular problems	measures often in combination with ... / remarks	particularly suitable for ...	references (examples)
initial measures: internal processes				
• introduction of plant propagules				
- seed mixtures	species composition and seed amounts, season of seed, site and cultivation in the first year	seed into existing vegetation layer normally not successful	mainly meadows, fens, pioneer and field flora	SER 1997, Keller and Kollmann 1998, Bosshard 1999
- introduction of collected seeds	ditto		ditto	Bosshard 1999
- distribution of plant material cut at seed maturity (hay)	ditto		ditto	Schiechtl 1973, Patzelt and Pfadenhauer 1998
- planting of single plants	competitiveness of surrounding vegetation	small scale restoration	ditto	Seeger and Pfadenhauer 1996
- distribution of cut woody plants			hedges	Benjes (1991)
• introduction of living plant communities				
transplantations and implantations (partial transplantation)	water regime, subsoil conditions		fens hedges dry meadows	Bruns and Gilcher 1995, Kloetzli 1980, 1987 Reschke 1980, Müller 1990
• introduction of consumers, destruents and symbiotic elements (e.g. mykorrhiza)				Nowak and Zaivanowits 1982
• manipulating the soil conditions				
- top soil removal to generate nutrient poor(er) conditions	de-eutrophication	regulation of water regime	meadows and fens on nutrient rich sites	
- top soil compaction	ditto	ditto	ditto	Marrs 1985
- soil deposition (e.g. gravel or nutrient poor humus)	ditto	ruderal sites, floodplains		
- initial fertilization incl. lime stock fertilization			difficult climatic conditions	
- soil acidification			acid grasslands on arable soils	Owen and Marrs 2000
- immobilization of soil nitrogen		by carbon addition	restoration of oligotrophic sites	Török et al. 2000
- introduction of legumes		N-fixation	ditto	
- mechanical loosening			compacted soils	
- introduction of earthworms			difficult growing conditions	

measures	decisive factors, particular problems	measures often in combination with ... / remarks	particularly suitable for ...	references (examples)
- introduction of mykorrhiza				Nowak and Zaivanowits 1982
- nutrient impoverishment by extensivication / regular biomass removing	soil type (sustainable nutrient input)		meadows and fens	Briemle and Elsässer 1992, Pfadenhauer and Klötzli 1996
• partial or complete destruction of the existing vegetation or reducing its vitality				
- ploughing or repeated harrowing			meadows and fens	Bosshard 1999
- grazing			ditto	Wittig et al. 2000
- black plastic film			ditto	Bosshard 1999
• local regulation of water regime				
- many different techniques, e.g. film or clay layer for soil waterproofing, ground water manipulation			rivers, fens	Bruns and Gilcher 1995, Grootjans and van Duren 1995
• manipulation of topography			river bed design	Brülisauer and Klötzli 1998
initial measures: external context				
• manipulation/regulation of water regime				
- single or permanent intervention; many different techniques, e.g. deletion of drainages	water nutrient content		wetlands, riverine ecosystems	Bruns and Gilcher 1995, Grootjans and van Duren 1995
• creating buffering zones				
- extensification or abolishment of agricultural use		to avoid or reduce nutrient influx	small islands of wetlands, riverine ecosystems	BUWAL 1994
• creating ecological networks and stepping stones				
- extensively used linear elements (hedges, field strips), animal passages		to provide new/additional habitats	cultural landscapes	Benjes 1991, Jedicke 1990, Amler et al. 1999
• facilitate natural dynamic processes				
- deletion of dams	water regime		riverine ecosystems	Brülisauer and Klötzli 1998, Schlüter 1992
manipulation of successional development				
• (re-)introduction of mowing or grazing				
- different regimes of cutting/pasturing			fens, grassland, forests	Hald and Vinter 2000
• herbicides			cultivated ecosystems	
• regular cutting of trees and shrubs			grassland, woods	
• periodical disturbance of the soil			gravel pits, ruderal sites	
• elimination of invasive plants				
- manual picking, herbicides, films, grazing			grassland	

7.11.6 Limits and potentials of restoration

Besides the limits in controlling the development of a complex system mentioned above, there are principal limits regarding time, environmental quality, spatial and budgetary restrictions.

The **time factor**, as far as it is system-inherent, is more or less incapable of being manipulated. Comparable to the development of an individual organism, an ecosystem passes through phases of youth to maturity. Pioneer habitats can be established within few years, for grasslands a youth phase of at least 10 years is expected, forests need 50-200 years or more, while ecosystems based on mature soil accumulation, for example bogs, need a development time of 200-5000 years to reach a mature state (Bradshaw 1997, Klötzli 1991a) and are, therefore, more or less impossible to be restored if completely destroyed.

Moreover, restoration projects often have to deal with **fundamentally changed environmental conditions** compared with the reference state be it locally (e.g. eutrophicated soil, pollution, changed groundwater table) or global (climatic change), be it regarding biotic (e.g. – alien or autochthone – invasive plant species) or anthropogenic (e.g. mowing techniques, disturbance) factors. Thus, normally it is impossible to recreate the "original state" of an ecosystem.

Nevertheless, the value of restored ecosystems for nature and landscape can be extraordinarily high even while still in their youth phase after a few years, in particular when endangered species find a new habitat or in destroyed landscapes where restoration is the only way to reintroduce a certain bio- and landscape diversity, as in intensively agriculturally used landscapes.

7.11.7 Restoration in practice: Objective, acceptance, monitoring

There is one fundamentally indisputable general principle of restoration practice and policy: Restoration must never be a reason to destroy and replace existing ecosystems. Nature from second hand has always comes off second best against the primordial protection of existing natural values.

A further important point of any restoration practice is to ensure an adapted, cost efficient, but scientifically rigorous monitoring (see Chapter 4.2). **Monitoring** is an effective and possibly the only way, which allows

- rational reactions to unpredicted developments in a given project,
- suitable targets to be defined as well as
- enlargement of pragmatic knowledge about restoration techniques and ecology.

This issue often is recognized too late or cannot be financed since the costs are not marginal and the value often is difficult to communicate to the sponsor, which wants to use the money for "visible things".

Only by an explicit identification and definition of the objectives and goals of a project can restoration ecology be truly valued (Bakker et al. 2000). The aims have to respect the unique context of each project – taking into account at the same time ecological (e.g. site conditions), historical (e.g. former state of the site), cultural, economical or social aspects (Bosshard 2000b). One component of this context consists of facts, another of values. The simultaneous **implementation** of both is decisive for sustainable solutions in practice. For example, top soil removing in ecological respect is a very successful method to restore species rich meadows, but is normally not accepted by farmers because destroying their most important good: soil fertility (Bosshard 1999). Moreover, for a large-scale implementation the financial requirements of this technique are too high. A good cost-benefit ratio therefore is an important prerequisite for a successful realization. There is a clear need for techniques, which are cheap to be applied over a large scale so that projects are financially viable even in developing countries (Edwards et al. 1997).

7.11.8 Outlook

While restoration ecology is a matter of science, practical ecological restoration is a highly inter- and trans-disciplinary issue. It touches the core of the contemporary crisis of environment and contains perspectives that can contribute to a new relation between man and nature. In this tension between scientific, societal and practical requirements restoration ecologists have to be aware of the – permanently changing – value system of the society that they serve. They must communicate with and motivate society on the targets and perspectives of ecological restoration.

7.12 Participation of different actors in a landscape

7.12.1 Introduction

Since nature conservation and ecological landscape planning has dared to venture out of the designated conservation areas and thus out of a legally well-regulated area into the entire, "unprotected" landscape, there was one experience which impresses itself on the majority of the projects. The more detailed, all encompassing and polished the ecological planning was, the less people were concerned and the less politicians wanted to know about it. In many European countries, piles of inventories, infra-structural planning and cultivated landscape concepts disappeared forever in official desk drawers (Zillessen 1993). No trace was left in the landscape, except for irritated farmers and other local stakeholders, who once again felt that "those at the top" only wanted to provoke them.

The reasons for opposition to and ineffectiveness of the landscape planning are not seen as arising from the content, aims or related restrictions, but the "how" of its development and communication (Wierbinski 1998). In particular the prevalent "decide-announce-defend approach" (Neugebauer 1999) provoked fundamental communication blockades. In the search for solutions, participation of the stakeholders emerged as a new paradigm for the process of planning and was recognized and established more and more as a prerequisite for a sound, sustainable planning approach.

For many committed ecologists, conservationists and planners the participation paradigm was and still is an unloved challenge. They argue that once again nature suffers when compromises have to be made, which differ from the ideal case scenario and – although seldom said – many feel offended by the lack of respect of their expertise and in their professional pride.

But reality contradicts both fears. Experiences with implemented planning projects, as well as epistemological considerations, show that a sound participative planning process leads to more creative, better site adapted and sounder results, both ecologically and socially.

The recognition of the fundamental importance of participation for a sustainable development of landscapes is related to the emergence of a similarly new role for the planners and ecologists within the planning process (Luz and Weiland 2001, see Chapters 7.1.5 and 7.9.6). Experts renounce their former authority and infallibility and become members of the planning process mediating (Bosshard 2000b).

Some reasons, prerequisites, perspectives and limits concerning the importance and potential of participative approaches for applied landscape ecology are outlined in this chapter, based on a literature review and experiences mainly in the German language area.

7.12.2 What is participation?

Participation in its fundamental sense is a **process** where different actors with different functions or within different hierarchical levels physically and/or mentally co-operate voluntarily. In landscape planning and landscape ecology, participation is also used in the sense of a **method** or instrument supporting or ensuring a self-motivated co-operation between different actors.

Koppen (1995) distinguishes three types of participation representing different degrees of involvement of societal groups or different actors into a valuation or decision making process: consultation, negotiation and consensus-building. The most consequent form of participation is **consensus-building**. It is possible if the parties recognize and believe that safe-guarding the interests of every party is the only guarantee for a stable, durable solution, and that the integration of different views is a useful way to detect and develop better solutions.

Participation in a comprehensive sense includes the following elements: Dialog, mutual interest with the conviction of the synergistic nature of different interests, ideas and viewpoints, the possibility to discuss both aims and measures, complementary role of experts and stakeholders, structures guiding the discursive process, subsidiarity in the sense of decision making on the level where it is most adequate (Bosshard 2000b).

7.12.3 Epistemological considerations

A basic step in every (landscape) planning approach is to outline the aims of a lay-out of the actual landscape status in relation to these aims. Both parts need an implicit or explicit definition of what is a "good landscape". From an epistemological point of view, the definition and assessment of landscape quality can never be "objective" - in the sense of generally valid (Bastian 2002, Bosshard 1997). Rather, every validation and every rationally motivated aim, even every statement or simple fact depends on the personal viewpoint from which the statement or valuation is derived (see Chapters 5.3 and 7.2). This is equally true for both experts and stakeholders. "What we observe, is not nature itself, but nature exposed to a particular question" (Heisenberg 1984). An everyday landscape planning database, like the actual vegetation, is not just a fact, but a consequence of the culturally prevalent viewpoint of bio-diversity. Only 100 years ago, not a single planner would have considered the distribution of plants as a component of planning, even though species were known and a lot of information may have been available (Bosshard 1996).

Which question we ask, what we accept as fact, how we view nature or a landscape, and whether we consider things to be good or bad, depends on our **point of view**. The latter, at least, is dominated by three aspects (Bosshard 1997):

- temporary, socio-culturally prevalent ideas of values,
- the physical project situation, and

– the personal background.

Nevertheless, as Bastian (2002) and Bosshard (2000b) showed, this does not mean that objectivity, facts or "truth" has to be considered as an illusion as nihilism or relativism claims, but that objectivity must be understood as a process which is driven by the complementary relation between different viewpoints. One of the most effective way to achieve an acceptable reality is the participative method confronting different viewpoints of the actors and leading to a new, landscape-specific synthesis (Bosshard 2000c). This process is able to generate suitable viewpoints and aims for the development of a given landscape in a given planning frame, and at the same time to clearly distinguish between suitable and less suitable viewpoints in this given context (Colquhoun 1997). Participation thus is an instrument of landscape recognition and landscape shaping, inside (mentally) as well as outside (in the visible landscape). In an epistemological perspective landscape ecology can therefore be defined as an integrative manner accommodating different views and approaches based on the concept of **complementarity** (Bastian 2001).

A scientific method to deal with this issue is called **heuristics**, based on contributions mainly by Fleck (1935), Habermas (1981) and Popper (1934). Wiegleb (1997) called this approach – when applied to landscape planning – **discursive paradigm development** (see Chapter 7.1.5). Bosshard (2000b) developed a methodology for an implementation of the approach in planning projects and describes experiences of its application. The iterative and participative procedure of **explicit assessment** allows the development of quantitative or qualitative aims for particular situations. The central element of the method is a checklist, a hierarchically structured collection of viewpoints to be reflected. Based on game theoretical considerations, Axelrod (1984) was able to show that cooperative discursive behavior results in an optimal joint solution and at the same time leads to the best individual results. A situation primarily perceived to be zero-sum may turn out to have a positive-sum.

These short philosophical and theoretical considerations shall underline the fundamental importance of participative, consensus-building processes for planning and particularly landscape planning with its inherent complexity, as well as landscape ecology itself.

7.12.4 Encouraging experiences with participative approaches

The paradigm of participation, cooperation and consensus-building has meanwhile has overcome the status of a theoretical approach, rather it is able to refer to a broad basis of – predominantly successful – project outcomes, both from the point of view of local people and of planners/governmental authorities. Not only are the results socially long-standing, in some projects they even surpassed conventional nature conservation planning both qualitatively and quantitatively, in part through the creative potential of the individuals involved (Bosshard and Gfeller 1992).

Based on an analysis of projects with a participative approach (e.g. Blum et al. 2000, Bosshard 2000b), lists of important **traits for the success of a participative approach** have been produced. Some are summarized here:

Successful projects were characterized by the formulation and communication of **concrete aims and sub-aims**. These aims were not treated as sacrosanct, but were adapted if demanded by new developments.

In most successful projects **key individuals** could be identified, who had a particular "process competence" (i.e. a capability to recognize problem situations and to react in a flexible, creative way, combined with a broad knowledge of the relevant facts). They also showed a particular project engagement and thus being able to integrate different interest groups and personalities into the project process on the basis of confidence.

Participative projects are successful if every group concerned has a more or less **vital interest** in several aims of the project.

Suitable, clear project organization provides transparency concerning the roles and competencies of the actors involved and also assures a framework for a fruitful communication. Furthermore, the adaptation of a given project structure to new situations was analyzed as a success factor. A particular role was played by permanent working groups, in which local actors were involved, and by particular communication concepts.

The **regional scale of projects** allows the development of solutions that were adapted to the local ecological and socio-cultural particulars. Conversely a uniform system would lead to an undesirable homogeneity of the landscape.

Methods, such as **exercises** introduced by skilled artists, scientists and planners, excursions or written information are able to raise the interest and motivation of the people concerned. Such encouragement leads to participation in the common process of landscape recognition and landscape shaping both mentally as well as the visible landscape.

7.12.5 Challenges, perspectives and limits of dialectic approaches

A participative planning strategy is not a simple approach; in reality the process is often blocked by many difficulties. Some challenges are to be mentioned here.

Renn and Webler (1992) give a list of traits that should be realized for successful participative discourses, these include awareness of the participants of the different rationalities and viewpoints of partners and the readiness to find joint solutions. Further, they give hints how these requirements are to be implemented.

An effective measure to support a successful process is the inclusion of mediation. **Mediation** is a method of settling an argument between parties by a neutral third person, the mediator. He actively takes part in finding a solution and keeps the planning process evolving. It is important to involve a mediator from the beginning of the project, not only when conflicts arise. Moreover, this person has to be professionally and ideologically neutral or an "outsider", who is equally accepted by every party (Knöpfel 1995, Neugebauer 1999).

The **time needed for communication** in participative projects is high and easily exceeds a third of the total planning budget. This has to be taken into account from the beginning, although this could aggravate the financing of a project. Nevertheless, in the long run successful participative projects often prove to be particularly cost-effective. An approach based on insight and responsibility will motivate people to invest their own efforts (Bosshard 1997).

Another difficulty for the start of new participative projects is that the financing bodies often want to know the results of a project beforehand. This demand is not compatible with participative methods, as the results are shaped by the process itself, and are thus not predictable.

How participative projects may work, will be outlined on behalf of two widespread project concepts in the following section.

7.12.6 Successful examples for a participative planning approach

A new policy with particular relevance to landscape and with a consequently participative approach is **Local Agenda 21**. It was first mentioned in Chapter 28 of Agenda 21, the United Nations' document agreed by world leaders in 1992, to promote the principle of sustainable development (see Chapters 7.1 and 7.9). It calls upon all local authorities/municipalities worldwide to draw up and implement local plans of action for sustainable development, in partnership with all stakeholders in the local community. Translating the well-known slogan "Think globally - act locally" into practice. Local authorities throughout Europe are increasingly using the Local Agenda 21 process to agree and implement local strategies for sustainable development. Internationally over 2,000 local authorities in 64 different countries are already engaged in the process, and of these about 1,000 are in Europe (Morris 2001).

Local Agenda 21 is the process that aims to involve local people and communities in the design of a way of life that can be sustained and thus protect the quality of life. Local authorities work in partnership with all sectors of the local community to draw up action plans to implement sustainability at the local level.

The participative quality of Local Agenda 21 is based on a number of **principles** (Morris 2001):

- recognizing the key role of local authorities in achieving local sustainability,
- showing global responsibility – both by reducing our own environmental impact and our effect on distant communities,
- sharing ideas and expertise with others, particularly in developing countries, to help them minimize their own environmental impact,
- participation of all sectors in the local community, and supporting local democratic processes, and
- integration of environmental, social, economic and cultural issues and quality of life of all local people.

Seven **components** build up a Local Agenda 21 process:

- managing and improving the local sustainability performance,
- integrating sustainability into the local projects, plans, policies and activities,
- awareness raising and education,
- consulting and involving the wider community and the general public,
- partnership action,
- producing a local sustainability strategy or action plan, and
- measuring, monitoring, reporting and reviewing progress.

Another example for a new participative planning instrument with particular relevance for landscapes are **Landscape development concepts**, abbreviated to LEK (from the German: Landschaftsentwicklungskonzepte). LEK represent the implementation level of the Landscape Concept of Switzerland and was accepted as guideline by the Upper House of Parliament in 1998. LEK take place on local or regional scale within the existing legal framework and aim to bring or to improve the process of a sustainable landscape development in a holistic way. LEK operate on a voluntary basis using i.e. economic incentives and are understood as processes, both with ecological and socio-cultural consequences. Targets, methods and results are being evaluated, discussed and adapted continuously between groups of experts as well as between stakeholders and experts. The experiences of this novel participative approach are promising. Since the beginning of 2001, a part of direct payments for agriculture therefore are linked with the existence of LEK projects.

Both instruments, Agenda 21 as well as LEK, recognize that local authorities/municipalities have a **crucial role** to play **in sustainable development** because they:

- represent and work on behalf of the local community,
- possess important local knowledge,
- carry out, commission or influence many of the services on which local quality of life depends,
- manage/own large parts of the built and natural environment,
- dispose on instruments and education, advice, and information,
- can catalyze partnerships with local economy, interest groups or consumers.

7.12.7 Conclusion

In which landscape do we want to live? This question is the fundamental motivation for research in landscape ecology and for landscape planning itself (Figure 7.12-1). At the same time, the question is fundamentally of social concern and cannot be delegated to landscape ecologists and planners. Landscape ecology therefore is a science with a strong social interrelation. Participation is a basic tool to respect and implement this epistemological interrelation in a sound, suitable and fruitful way.

Figure 7.12-1: In which landscape do we want to live? The answer to this question is fundament and motivation to all research in landscape ecology and to all landscape planning projects: Ortisei (St. Ulrich in Southern Tyrol, Italy) (Photo: O. Bastian 1998)

The poor acceptance, high failure rate and the ineffectiveness of the "classical" top down or decide-announce-defend planning approach supports this theoretical consideration. It seems that no real development or sustainable realization of ecological and esthetical visions can be achieved in the landscape without the involvement of the stakeholders. In a modern society with its democratic consciousness stakeholders are needed to help in formulating the objectives and implementing measures right from the start.

However, the participation paradigm must not only be regarded as an instrument to solve conflicts or raise the acceptance or efficiency of a project. In this restricted sense, participation encompasses the danger of a suggestive, dishonest concept, trying to get round the resistance of stakeholders. Participation in its effective, fundamental sense, based on the epistemological principles of complementarity, includes the conviction that participative solutions will also be more creative, better balanced and sound – in short better – than planning resulting from the contributions of a few planners or biologists.

The consequence is, that applied landscape ecology no longer should be considered as a scientific and technical field, but has to include inherently the socio-cultural context which is part of every landscape.

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Glossary

abundance: number of organisms related to an area or time unit
archeophytes: plants introduced in pre- and early historical time
area (range): geographical space inhabited by individuals, populations, and species
attendant plan of landscape management (German: Landschaftspflegerischer Begleitplan): describes the major long-term effects of a proposed action on nature and environment. It shows the steps required to avoid and reduction of environmental nuisances caused by the project as well as the steps to compensate for unavoidable impacts. It completes the → environmental impact study
barrier: spatial obstacle between similar → patches
benefit principle: analysis of complex action alternatives to serve the purpose of ordering the stake-holders' preferences regarding a multidimensional target system
biocoenosis: assemblage or community of plants and animals with the same or similar ecological demands in a distinct area (→ biotope)
biocomplexity: functional diversity of organisms, communities and → ecosystems
biodiversity: qualitative, quantitative and functional diversity of biotic → landscape compartments (organisms, communities and ecosystems)
bioindicator: organisms or their community whose life functions are correlated to certain environmental factors so tightly that they can be used as a pointer for this phenomenon
biosphere: the part of the earth populated by organisms; the ecosystems as a whole
biotope: separated living space of a specific community of plants and animals (→ biocoenosis) characterized by uniform living conditions; the term has a stronger synecological focus than → habitat
biotope complex: association of single single biotopes occurring at more or less regular intervals
biotope mapping (habitat mapping): registration and cartographic presentation of biotopes valuable for → nature conservation (selective biotope mapping) or of all biotope types within an area independently of their value for nature conservation (exhaustive biotope mapping)
biotope network (biotope cross-link net): spatial connection of biotopes realized only via functional relationships of organisms or communities (→ connectivity)
biotope type: group of kindred or similar single biotopes

biotope value (habitat value): degree of suitability of an area as a living space for plant and animal species
boundary: edge of a → patch, a → landscape element, or a → landscape unit
buffer: transitional area acting as a filter or a mitigator of disturbance processes
buffering: capacity of an environmental medium (e.g. soil) to withstand changes in one (or several) of its parameters (e.g. pH-value)
capacity of the landscape to perform its essential functions: ability to yield ecological outcomes (functions, potentials) depending on the spatial-material structure, function, and dynamic as well as the materials, energy, and processes of landscape ecosystems
care of the countryside: totality of all measures (including → nature conservation, and → landscape management) to sustain and develop landscapes
carrying capacity: the maximum admissible use of ecosystems in their landscape, compatible with the long-term preservation or reproduction of the necessary basic conditions
catchment area, drainage area: area delimited by surface or subsurface watersheds draining to a specific point
catena: general typical two-dimensional sequence of → ecosystems / → ecotopes along an ecological gradient; in soil sciences also a soil sequence
characteristic: special combination of natural and cultural elements in a landscape which, as a rule, has developed over a long historical period. It is an essential part of the → landscape image
chorological (→ dimension): related to the investigation of heterogeneous areas (patterns, mosaics) consisting of → topological basic units
climate change: global change of the climate referring mainly to the rise in temperature during the recent decades, but also to changes in precipitation, radiation and glaciation
connectedness: refers to structural links between elements of the spatial structure of a landscape, and can be described from mappable elements
connectivity: degree of functional connection within a landscape
corridor: spatial connection between similar → patches
cultural landscape: 1. a landscape dominated ecosystems modified by humans; 2. → historical landscape worthy of protection
devastation: far-reaching, usually irreversible destruction of ecosystems and landscapes
digital terrain model (DTM): digital storage of elevation data in regular or irregular networks (especially triangulation) with analytical functions and presentation tools
dimension: domain with the same textual information and adequate scale interval requiring a certain spatial order of size of the objects investigated as well as a specific intensity of analysis and synthesis; reflected in the selection of features denoting the selected objects (→ topological, → chorological, regional, global/zonal dimension)
disciplinarity: differentiation and (especially historical) boundaries within sciences. Within disciplinarity, there are different degrees of effort to contact other disciplines, from mono- via multi- and pluri- to crossdisciplinarity
distribution area: area of occurrence of a taxonomic unit (genus, species, subspecies, population) of plants or animals
disturbance: spatial event that leave effects in a landscape
disturbance regime: pattern of different disturbances in time and space across landscapes
diversity: measure of the variety of phenotypes (structures, species) and the evenness of their distribution associated with a biocoenosis, an ecosystem, or a spatial unit (→ landscape diversity)
drainage: artificial regulation of the → soil water balance
ecochore: (choros: greek "space"): a spatial manifestation of multiple → ecotopes of different structure and functioning spatially connected with each other and organized by a new emerging structure and functioning on a higher level of abstraction. Ecochores

represent the landscape sphere and its related systems of landscape complexes (→ ecosystems) within the → chorological dimension (spatial meso scale)

ecofactor: 1. part of → landscape factor; 2. abiotic factor necessary for life; 3. biotic factor influencing other ecofactors

ecological assessment: evaluation of landscape elements and landscapes with respect to their ecological capacity

ecological balance sheet analysis: comparative estimation of the landscape capacity before and after an interference

ecological complexity: functional diversity among → landscape elements and compartments, including interactions between soil and biota, or between the atmosphere and the vegetation

ecological connection matrix: method of combining single features into a general statement within the framework of ecological assessment

ecological indicator value: recognizable ecological responses of plants to site conditions in their natural competitive milieu

ecological planning: planning urgently aimed at the preservation of the basis of the livelihood basis of man, animals and plants and at the reduction or prevention of damaging effects on the natural balance

ecological risk assessment: methodology to clarify mutual influences on the landscape balance by different land use processes. First, the single → indicators are combined to "the intensity of potential impairments" and to "the sensitivity to impacts", and then, to "the risk of impairments"

ecological-sociological group: group of plant species responding in a similar way to important site factors and therefore associated in nature

ecology: science of the interactions between organisms and their abiotic environment; science of the structure, function, and development of the environment

econ: a definite part of the landscape with vertical structure of landscape components. These components determine characteristic processes between the → landscape compartment spheres. Thus, an econ is a small delimitable area that has been chosen out of a larger → landscape unit serving as a basis for the analysis of vertical landscape structure and functioning

ecosphere: portions of the universe favorable for living organisms and in which all ecological processes are contained

ecosystem: functional unit of the → ecosphere, consisting of living beings, and natural abiotic and man-made components which are interrelated and interacting with their → environment through energetic, material and information processes

ecotone: contact or transition zone between adjacent ecosystems having a set of characteristics uniquely defined by spatial and temporal dimensions, and by the strength of interactions between their adjacent ecosystems. An ecotone can vary in size and ecological functioning

ecotope (greek "topos": locality): the elementary unit of a landscape, homogeneous for a particular pattern or function

ecotope pattern: ecological spatial unit consisting of several → ecotopes characterized by typical structures, processes, and interrelations

edaphic factors: soil factors like water and nutrient availability, pH-value, texture

edaphon: the totality of organisms living in the soil

edge effect: the presence of higher concentrations of organisms at the edges of an ecosystem / a → patch

emergence (latin: emergere = to emerge, to come forth from an inferior position into one of superiority): change of ecological content conceived as characterized by the appearance at different spatial dimensions (or different levels of abstraction) of wholly new and unpredictable characteristics or qualities through the rearrangement of preexistent entities environment: organisms' surroundings and their community with the totality of factors influencing them

environmental impact, environmental interference: alteration of shape or use of landscape parts impairing the natural processes and capacity or the landscape itself considerably

environmental impact assessment: examination of possible effects of proposed actions on the natural and cultural environment. The projects which must be checked (like refineries, steelworks, highways, airports) are listed. It was introduced in Europe during the 1980s with the main purpose to avoid environmental nuisances before they arise

environmental impact study: describes the major effects of a proposed action on environmental resources and potentials. It describes steps that should be taken to avoid and to reduce environmental nuisances caused by the project. The environmental impact study is a document which must be submitted to national or regional authorities for the environmental impact assessment

environmental protection: totality of measures taken to maintain the basis of natural livelihood

environmental regime: pattern of different environmental conditions in time and space across landscapes

environmentally sustainable development: part of → sustainability. It comprises the primarily ecological aspects: compatibility of societal and economic forms of resource use with the → carrying capacity of the → environment; in environmental-economic terms: an increase in the efficiency of resource use; in socio-ecological terms: the modification and replacement of resource-wasting lifestyles and patterns of consumption and production, i.e. sufficiency. Institutional aspects comprise organisational and procedural aspects including the practitioners, who promote and put into effect environmentally sustainable development

equilibrium, ecological: relatively stable state of ecosystems characterized by self-regulating capability

eutrophication: enrichment of nutrients leading to changes within (parts of) an ecosystem

evaporation: water evaporation from soil surfaces and from water bodies

evapotranspiration: sum of water evaporating from plants (by transpiration), and from soils and water bodies

exchange capacity: totality of ions fixed to clay minerals and humus in an exchangeable manner

extensification: decreased input of yield-promoting resources and/or labor per unit area (restriction or relinquishment of use)

fallow field: field in which crop cultivation for one or several years

field-moisture capacity: measure of the natural water storage capacity of soils

filter function: ability of the soil to retain, precipitate or transform coarse, colloid or finely dispersed substances, so that the quality of surface or subsurface water is not impaired

filtering capacity: maximum amount of pollutants including toxic chemical or biological substances that can be retained by soil without attaining the groundwater

flora: totality of plant species in an area

footprint, ecological: the equivalent area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on earth that land may be located

fragmentation: 1. degree of functional disconnection within a landscape; 2. a process by which forest cover is opened and isolated woodlots are created

geobiocoenosis: broadly synonymous with → ecosystem

geocomplex: relatively closed subset of the natural environment whose → geocomponents interconnect resulting in a homogeneously reacting framework of effects

geocomponent: relevant component of the → geocomplex, which is characterized by various features and is composed of several → geoelements (e.g. humus layer, mineral soil, soil moisture regime)
geoelement: basic component of the → geocomponents; it can be measured (e.g. soil pH-value, clay content of the soil, slope declination, species number)
geographical information system: → landscape information system
geotope: → ecotope
global change: environmental changes at the global scale including changes of climate, radiation, sea level, sedimentation, land use, species invasions and energy cycling
green tourism: the concept demands a deeper consideration of environmental and social concerns in tourism instead of solely focussing on economic benefit
groundwater protection function: natural ability of the landscape to protect groundwater against pollutants due to the structure of the covering layers as well as vegetation cover
groundwater recharge: input of infiltrating water to groundwater
group of species: plant or animal species having equal or similar ecological and/or systematic characteristics
habitat: characteristic living space or site of a species. The term has a stronger autecological focus than → biotope
habitat connection (compound biotope): sum of area-related (direct) contacts between biotopes
habitat structure: characteristic features of a vegetation stand as well as of abiotic landscape elements which are essential for the existence of certain animal species
hemeroby: degree of human influence on a habitat or on the vegetation cover compared with the natural conditions (→ naturalness)
hierarchy: considers a system as part of a larger system, and composed in its turn of subsystems
historical landscape: landscape with predominant elements that are adapted to historical conditions of land use
holism: comprehensive ecological approach; the features of the units of the higher hierarchical level cannot explain as the mere sum of its parts
humus: totality of the dead organic soil substances of plant or animal origin
incidental organisms: plants/animals that are not native but introduced by man into a certain area
indicator: reaction variable whose spatio-temporal condition can be registered comparatively simply and that has a surpassing explanation content with respect to the underlying problem
intensity of use: measure of the productive factors (labor, capital) applied per area unit
interdisciplinarity: a common axiome for a group of related disciplines is defined. The organizing principle is two-levelled, multigoaled, and with coordination on the higher level
interference: the impact on the shape or the utilization of land plots in a way which hampers the balance of energy and matter, or disfigures the scenic features of the landscape
interference analysis: ascertainment and interpretation of the superposition of various land use types at the same area
invasive species: species that establish in an aggressive way and may cause economic damage
island theory: theory of island biogeography addressing the relation of species diversity mainly to the size, the distance and the age of an island. This has been applied to terrestrial isolates of → landscape elements as well
land use: usage and treatment of the earth's surface and its natural potentials and resources for the fulfilment of human needs
land use change: change in the intensity and kind of land use, and of its spatial distribution

land use form: management practice within the same type of land use (agriculture, forest, traffic, ...) but differentiated through the methods and intensities applied

land use pattern: spatial mosaic of different land use types

landscape: part of the earth's surface with a uniform structure and functional pattern. Both appearance and components (→ landscape factors: relief, soil, water, climate, flora, fauna, humans and their creations) including their spatial position are concerned. Landscape is not only the sum of single landscape factors but an integration of the → geocomplex. Thus, landscape involves different spheres: inorganic spheres, → biosphere, and sociosphere

landscape analysis: analysis of the natural (ecological) and anthropogenic properties, processes and dynamics of the landscape

landscape architecture: a complex of measurements taken to create a landscape according to societal goals with aesthetic viewpoints in the foreground

landscape assessment: evaluation of the current/potential state of a landscape and its functional pattern concerning utilization, performance and ecological capacities

landscape balance (landscape energetics, balance of nature): interweaving and framework of effects of abiotic landscape factors and organisms within a landscape including exchange processes between adjacent landscape units

landscape change: qualitative landscape alterations concerning the balance of matter and energy, the natural potential and the external appearance

landscape compartment: functional unit within a landscape representing a portion of an ecological sphere (e.g. soil, air, water, biomass)

landscape conservation: measures taken to sustain and maintain the natural and cultural landscape properties

landscape damage: impairment of the external appearance and of the efficiency of the landscape balance caused by human activities

landscape development: landscape alteration determined by nature and influenced by man (→ landscape change); in → landscape planning: measures taken to protect, to care and to shape an ecologically efficient and aesthetically appealing landscape

landscape diagnosis: assessment of the capability and suitability of the landscape for → land use, and assessment of the development potential of a landscape

landscape diversity: number, differences between and functional traits of → landscape elements

landscape dynamics: processes within the landscape; movement of matter, energy and organisms

landscape ecology: ecologically oriented branch of landscape research focussing attention on the analysis and synthetic treatment of the complex interactions between abiotic and biotic features of the landscape complex

landscape element: 1. → landscape factor; 2. spatial, temporal or functional unit within a landscape with characteristic traits and performances (e.g. forest, arable field, lake, river, hedgerow, motorway)

landscape experiment: manipulation of landscape elements and establishment of certain environmental qualities to simulate future site conditions or the effects of changes in → disturbance regimes

landscape factor: characteristic component of a landscape e.g. rock, relief, soil, climate, vegetation as physical landscape factors as well as settlements, → land use, and industry as cultural landscape factors

landscape function: capacities realized by landscape

landscape heterogeneity: spatial or temporal variability between → landscape elements

landscape image (scenery): visually perceivably outward form of a landscape, taking no account of the associated processes

landscape indices: algebraic indices describing → landscape structure (e.g. shape of landscape elements, their edges and pattern)
landscape information systems (LIS): information system for natural resources and land use as well as fauna and flora. Regularly updated databases are a prerequisite and a component of the analytical functions of a LIS and of their presentation tool, too. Typical requirements are the estimation of ecological effects of planned sanctions, the report on the current situation of nature and the landscape and the simulation of short term environmental changes
landscape inventory: number of types and individuals of → landscape elements
landscape management: totality of measures taken to sustain or to reestablish an efficient landscape with respect to economic, ecological and social aspects
landscape modeling: simulations and prognosis of virtual conditions based on mathematical algorithms
landscape plan: representation of goals and measures of nature protection and landscape management on the communal level
landscape planning: instrument of policy, concerned with the management of landscapes, particularly focussed on nature conservation and preservation of scenic beauty
landscape prognosis: estimation and assessment of future spatio-temporal → landscape changes
landscape research: scientific sub-discipline of geography dealing with landscape investigation
landscape structure: three dimensional spatial organization at the surface of the landscape: i.e. the → pattern of → geocomponents or → landscape elements, disregarding processes and functional relationships
landscape unit: pattern of → landscape elements in the → chorological dimension, characterized by both natural and anthropogenic → landscape factors
Leitbild: target system describing fully the aspired state of a spatial unit, taking into consideration the relevance of the diverse objectives. System-immanent target conflicts are dealt with by means of a preference ranking or a balancing of interests. Leitbild for the landscape development: summarized presentation of the desired landscape status to be achieved in a specific landscape in a foreseeable time frame
limiting value (critical value): strongly binding (mostly fixed by law) variable denoting the limit of not unreasonable or admissive stress of man and environment
local land use plan (master plan): representation of the actual and intended land use within a community
macro(geo)chore: a region composed of an aggregation of mesochores
meso(geo)chore: an aggregation of → microchores
meta-disciplinarity: approaches that transcend disciplines such as → interdisciplinarity and → transdisciplinarity. Cooperation and coordination exist among the disciplines involved
metapopulation: functionally interacting populations of a certain species
micro(geo)chore: a combination of → geotopes associated on a higher level. They have new properties beyond the mere sum of the parts. The pattern of geotopes primarily reflects landscape-forming conditions (history). On average, microchores consist of 80-100 geotopes, and they have an area of 3-30 km^2 (in Saxony, Germany)
minimum area: smallest area necessary for the reproduction and long-time survival of a (breeding) pair, a population, species, biocoenosis, or a whole ecosystem
monitoring: observation system to indicate changes in biosphere or landscape condition mainly in terms of human impacts
mosaic: aggregation of spatial patterns within a landscape
nano(geo)chore: an aggregation of a few → ecotopes
natural landscape: 1. landscapes with predominantly natural mechanisms of regulation; 2. any spatial part of the geosphere characterized by naturally determined uniform struc-

ture and functional pattern of its natural components (sometimes also called physical region or → nature area)

natural potential: ability of landscapes to yield social benefits

nature area (German: Naturraum): entirety of natural (abiotic and biotic) elements in a landscape. Synonymous terms are: natural area, natural sphere, physical region, → natural landscape

nature conservation: totality of scientific, administrative, and practical measures taken to sustain the living and the inanimate world of nature

natural resource: basis of livelihood of society taken from nature

naturalness, degree of: a measureading of human influences on the vegetation (→ hemeroby)

neophytes: plant species introduced in the modern age (since the year 1492)

neozoons: animal species introduced in the modern age (since the year 1492)

network: system of functional connections at the landscape scale

noosphere: the mental sphere of humans that is characterized by perception and reflection and where humans interact with the physical-material reality of the geo- and biosphere

objectives of environmental quality: spatially and temporally defined qualities of natural resources, potentials and functions to be maintained or developed

organic agriculture: organic farms usually must satisfy regulations, as follows: they may not use chemical fertilizers and pesticides; they have to maintain or improve fertility and biological activity of soils by crop rotations that include pulse crops or green manure, by ploughing in organic matter, and by livestock manure; animals have to be kept in a manner appropriate to their physiological and behavioral needs; stables have to offer enough space for movement and enough litter, fresh air and daylight, and animals may not be tethered; and in summer all animals must have access to pastures

patch: spatially discrete landscape element with clear spatial boundaries

patch dynamics: temporal changes in the distribution of patches within a landscape

pattern: content and internal order of a heterogeneous landscape unit, or: non-random organization of → patches

pedotope: area (in the → topological dimension) with the same / very similar soil features

physiotope: smallest ecologically relevant spatial unit of landscape with a (quasi-)homogeneous physical-geographical structure and ecological traits depending on the abiotic site conditions

potential natural vegetation: vegetation status to be expected if human impact on the present vegetation were be stopped suddenly, according to the present location conditions and according to the present species composition

project-related planning: approach to regional planning, concentrated on the essentials of regional policy, setting priorities to certain projects; more flexible than integrated development planning

reclamation: → rehabilitative work carried out on the most severely → degraded sites without aiming for full → restoration

recreation: 1. holiday, break, relaxation; 2. attempt to reconstruct an ecosystem on a site so severely disturbed that → restoration is not possible, or a new creation as a substitute for a destroyed biotope elsewhere, on a site where this type of biotope has never existed

recultivation: the regeneration of ecosystems for cultivation purposes

red book: list of species, biocoenosis or ecosystem types threatened, on a local or regional scale, by human activities

regeneration capacity: extent of the ability of an ecosystem to compensate for stresses and damages within the scope of matter cycle and energy flux

regional planning: complex procedures of planning to realize the aims and guidelines of → regional policy. It shall coordinate and regulate the competing objectives of regional development in a precautionary way regional policy: the whole political efforts for the complex development of regions, focussed on public welfare and the compensation of spatial disparities

regulation: re-establishment of previous ecosystem conditions triggered by exo- and endogeneous factors

rehabilitation: any attempt to restore elements of structure or function of an ecosystem, without necessarily attempting complete → restoration

renaturation: transformation of habitats altered by man into a situation closer to nature

resilience: capacity of an ecosystem to return to the original state after a → disturbance

resource management: data-based steering of use of resources

restoration: return to a former original state. Ecol. Restoration aims to trace back → ecosystems or → biotopes in more natural states providing new live space for endangered, rare or typical organisms and forcing back organisms populating areas highly influenced by human activities

romanticisation of landscapes: harking back to the Romantic ideals of unspoiled landscapes, solitude, and individuality when perceiving and shaping landscapes

scale: a geographical dimension expressed in area and distance, or for a map, a fraction. Therefore, large spatial scales deal with large fractional scales, small areas, short distances and large details, best expressed as "large map-scale". On the other hand, small spatial scales deal with small fractional scales, large areas, great distances and fewer details, best expressed as "small map-scale". The terms "broad scale" (large extent) and "fine scale" (small extent) should be used to express the extent that is represented by the boundary of a study area under consideration. There is a completely different understanding of "small scale" and "large scale" in German and English/American literature: German landscape ecologists and geographers use the term "scale" like cartographers: So 1:100,000 is a smaller scale than 1:10,000. On contrary, for English and American ecologists a small scale is coupled to a small area; a large scale to a large area. In this book, we endorse the version of English and American ecologists, not the version of Germans.

scenery: → landscape image

second home: properties owned or rented on a long lease as the occasional residence of a household that usually lives elsewhere

sensitivity: the ability of a system to respond after an influence by self-change, and similarly to indicate such an effect

site: spatially delimited domain of the occurrence of geological or biological phenomena

siting: decision making on locations or location lines of projects in regional planning or landscape planning

soil: alive top weathering layer of the earth's crust composed of mineral as well as organic matter

soil acidity: pH value of soil

soil degradation: decrease of soil quality due to natural or human influences (e.g. → soil erosion, compaction, acidification, salinization, humus loss)

soil erosion: soil loss, mostly human-induced, by means of running water or wind

soil fertility: soil productivity; the description of the yield potential depending on soil properties and agricultural management

soil form: pedological mapping unit consisting of a soil-systematic master form with a shortened form for the substrate from which the soil profile arose

soil loss: soil wastage caused by erosion

soil protection (soil conservation): measures and recommendations for soil protection, maintenance, and redevelopment

soil skeleton: coarse components of the mineral soil (e.g. gravel, stones, blocks)

soil taxation (Germany): descriptive and cartographic inventory and assessment of the yield potential of agricultural areas; concept developed within the 1930s for the tax valuation of soils

soil texture: granulation type, assessment of quality of the mineral soil material due to its grading (e.g. clay, loam, loamy sand)
soil type: summarizing term for soils that have arisen from the combined effects of soil-forming factors of the same kind, and characterized by typical horizons and special features
soil water: the water in the soil (groundwater, attached groundwater, backwater and mobile water) not including the bound crystal water
space management: data-based steering of patterns of space use and functions
spatio-temporal management: considers the relationships between societal time frames and spatial use frames and optimize both mutually in all planning tasks
species area curve: graphical description of the relation between number of species and area. Up to an absorption point it is valid: the greater the area size the larger the number of species
stability, ecological: persistence of an ecological system as well as its ability to return to the initial situation after alteration
standards of environmental quality: substantial evaluation critera for → objectives of environmental quality
stepping stone: island biotope serving as stop over station and thus helping the spread of populations over long distances
stress: totality of influences on organisms, populations and ecosystems exceeding normal natural conditions
succession: temporal sequence of species or habitats of a biotope leading from an initial to a climax stage of a dynamic equilibrium
suitability for land use: criteria for acceptable types and intensities of land use with respect to the regeneration ability of landscape, nature, and ecosystems on different levels of integration
surface sealing: man-made soil cover or sealing (e.g. by buildings, streets) with a negative influence on important soil functions (e.g. water filtering, groundwater recharge, habitat)
sustainability: everlasting preservation of the efficiency of ecological systems to yield benefit for present and future generations
synergism: convolution of substances, factors, or organisms whereby the individual components benefit from each other in such a way that the overall effect is greater than the sum of all individual effects
systems theory: focuses on the connections and relationships among elements in a whole instead of looking at separate parts
systems view: a dynamic concept that perceives the world, not as a fixed reality, but as an ever-changing phenomenon that might be unstable, uncontrollable, even chaotic
tessera: a small surface area equipped with measures for representative acquisition of data describing the dynamic of this landscape. It follows the method of landscape ecological complex analysis
topological (→ dimension): related to the investigation of homogeneous (better: quasi-homogeneous) basic units of the landscape (e.g. → geotopes)
topology: position and disposition of (geometric) objects in space
Total Human Ecosystem: the complex sum of all landscapes, in which humans are integrated and interact. It is the highest level of ecological hierarchy on a global scale formed by humans and their total environment
transdisciplinarity: entails the cooperation and coordination of all disciplines and subdisciplines related to the field of research. It coordinates science, education, and innovation from society within one system. The systems approach is the most basic principle. Practitioners and interests from science and outside the academic world are involved
trophy: status of an ecosystem with respect to the supply of available nutrients

urban biotope (habitat) mapping: method of mapping (normaly in the scales of 1:10,000 to 1: 25,000), characterizing (by flora and fauna) of urban biotopes by using land use types; a tool for handling nature conservation in the urban planning process

urban climate: the changed environment of urban areas establishes a specific urban climate at the meso climatic scale in larger cities and towns different from the climate of the city's surrounding. It is characterized by higher temperatures and lower precipitation rates, giving a dryer and warmer climate than that of the surroundings. The urban climate is itself highly differentiated into local microclimates of green areas or different built-up areas

urban ecology: an integrated field of several sciences from different areas and from planning with the goal of an improvement of human conditions and long-term, environmentally-sustainable urban development

urban green space plan: sectoral plan of → nature conservation and landscape management at the level of the legally-binding land-use plan

urban nature conservation: complex of measures in urban planning and development to secure nature of all kinds (not only rare species and habitats) under urban conditions with the aim of developing a closer contact between urban dwellers and their natural surroundings. It includes traditional species protection as well as citizen participation to develop urban wildlife areas and (recreational) use of urban green spaces

urban wildlife areas: areas in an urban environment without specific maintenance so that natural succession can take place. These areas can have a simple infrastructure, such as trails or observation places for visitors. Most of them are actually not specifically valued by the urban administration. They are only partly protected and often seen as waste land

urbanization: development of urban lifestyles, activities and behavior in formerly rural spaces

vector: spatial, temporal or merely functional connection between → patches. This also includes connections between different patches. Agents such as the wind or animals can act as vectors as well, when they transport matter or diaspores

vegetation: totality of plant communities in an area

wasteland (badlands): land that is not (or not any longer) managed by man (e.g. fens, heath, agricultural fallows, gravel pits, deposits or heaps in mining areas)

yield potential: theoretical capacity of the vegetation to produce usable biomass. The yield potential is determined by soil factors, solar radiation, temperature, and precipitation

zoning: assignment of areas to certain types of landuse. Instrument of regional and landscape planning for the development of sustainable land use and a tool for the restriction of inappropriate land use

Index