The Association of Academies of Sciences in Asia (AASA)

TOWARDS A SUSTAINABLE ASIA

ENVIRONMENT AND CLIMATE CHANGE

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Beijing

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With 38 figures

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Thematic Report of the AASA Project "Sustainable Development in Asia"

TOWARDS A SUSTAINABLE ASIA: ENVIRONMENT AND CLIMATE CHANGE

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Abbreviations

AASA	Association of Academies of Sciences in Asia
ADB	Asian Development Bank
AEC	Asian Economic Community
APSC	ASEAN Political and Security Community
ASCC	ASEAN Socio-Cultural Community
ASEAN	Association of Southeast Asian Nations
BYD	Build Your Dreams
CACE	China-ASEAN Cooperation Center for Environmental Protection
CDM	Clean Development Mechanism
CEP-BCI	Core Environment Program and Biodiversity Conservation Corridors Initiative
CH_4	methane
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	carbon monoxide
CO_2	carbon dioxide
CTI	Coral Triangle Initiative
EANET	Acid Deposition Monitoring Network in East Asia
EAS	East Asia Summit
E-HII	estimated heat island intensity
EMM	Environment Ministers Meeting
ENSO	El Niño-Southern Oscillation
EPA	Environmental Performance Assessments
EST	environmentally sound technology
GDP	Gross Domestic Product
GEO-4	The Fourth Global Environment Outlook
GHG	greenhouse gas
GLIMS	Global Land Ice Measurements from Space
GMS	Greater Mekong Subregion Cooperation
HII	heat island intensity
IAI	Initiative for ASEAN Integration
IPCC	Intergovernmental Panel on Climate Change
IPCC AR4	Intergovernmental Panel on Climate Change, The Fourth Assessment Report
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management

MDG	Millennium Development Goals
MEP	Ministry of Environmental Protection of the People's Republic of China
NASA	The National Aeronautics and Space Administration
NEASPEC	North-East Asian Subregional Programme for Environmental Cooperation
NGO	non-governmental organization
NO_x	nitrogen oxide
N_2O	nitrous oxide
NSEC	North South Economic Corridor
OECD	Organisation for Economic Co-operation and Development
PDP	Power Development Plan
$PM_{2.5}$	fine particulate matter
PM_{10}	particulate matter $< 10\mu m$
RAINS-Asia	Regional Air pollution INtegration and Simulation-Asia
RPTCC	Regional Power Trade Coordinating Committee SEA
SEA	Strategic Environmental Assessments
SGD	Submarine Groundwater Discharge
SMCA	Spatial Multi-Criteria Analysis
SO_2	sulfur dioxide
SRES	Special Report on Emissions Scenarios
SST	sea surface temperatures
TAR	Third Assessment Report
TEMM	Tripartite Environment Ministers Meeting
UHI	urban heat island
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNSD	United National Statistical Data
UNSO	United Nations Statistical Office
USD	United States dollar
WDI	World Development Indicators
WHO	World Health Organization

Foreword

Asia is not only the largest and most populated continent in the world, but also the region with the most diverse development models and most dynamic economies. In the past half century, Asia has been witnessing rapid economic growth and playing an increasingly more important role in world's political and economic arena. At the same time, Asia has developed the commonly-called "Asia Model", which has attracted worldwide attention. The Asia Model shows a new way for the developing nations or late-development countries on how to realize industrialization and modernization. All these achievements are made by Asian countries with a focus on the advantages of their late development, re-examination of their internal cultural values, active absorption of modern S&T and management experiences and constant exploration and innovation.

These social progresses have made great contributions to the realization of the UN Millennium Development Goals and have played a pioneering and demonstration role on what can be accomplished in today's world. However, Asia is facing big challenges. The most prominent one is that the rapid development of Asian economies is based on large input of production factors at the huge expense of natural resources and environment, which has been sharpening the conflicts in population, resources, environment, socio-economic development. The sustainable development in the region is being severely threatened and challenged. The rethinking and questioning of the Asia Model in the international community is growing especially in the era of post Asia Financial Crisis and Global Financial Crisis.

It is not only a common challenge for the governments of Asian countries, but also a common task for the Asian scientific communities to cope with the resources and environment crisis and to seek a new way of sustainable development in Asia. AASA, as a non-governmental and regional international scientific organization with 26 member academies, is mandated to initiate and conduct investigation on issues concerning S&T, economic and social development. As early as April 2007, AASA proposed to initiate a project on "Sustainable Development in Asia" (SDA) within AASA framework in the hopes to provide consultation and advice for national and regional governments in Asia and relative international organizations. This study proposal was approved at AASA board meeting held in Russia in August 2007 with the Chinese Academy of Sciences as the initiator. The project covers environment, energy, resources and culture with the establishment of four working groups among AASA member academies.

Soon after, the SDA project was officially launched and implemented at different levels. The efforts include the clarification of the research content, emphasis, structure and division of tasks. Various meetings at the working level and international workshops have been held to coordinate the research activities and project progress: the first international workshop under this project was held in February 2008; the AASA Workshop on Sustainable Energy Development in Asia in November 2008; the AASA Workshop on Agricultural Culture and Asian Sustainable Development in August 2009; and the AASA Workshop on Environment and Resources in September 2009.

With the joint efforts of AASA member academies, the SDA project has now come up with a series of studies including four thematic reports, namely, "Towards a Sustainable Asia: Energy", "Towards a Sustainable Asia: Environment and Climate Change", "Towards a Sustainable Asia: Natural Resources", and "Towards a Sustainable Asia: The Cultural Perspectives" . Based on these four reports, a synthesis report has also been written entitled: "Toward a Sustainable Asia: Green Transition and Innovation". All these reports have looked deeply into the common issues and challenges for the Asian sustainable development from different perspectives.

The synthesis report is an integration and extension of the four thematic reports. It aims at the major resource and environmental challenges and issues in Asia in the general context of the challenges of financial crisis and climate change, and in line with green transition and innovation in Asia. Of its major findings, it includes: the diagnosis of key resource and environmental issues in Asia, such as water, minerals, land resource, environmental pollution, eco-degradation, energy and environment and climate change, the revelation and reflection of the diverse, different, complicated and severe nature of resource and environmental issues in Asia, the systematic analysis of the main driving forces and future trends of resource and environmental changes in Asia, the empirical analysis and discretion of current evolution of the relationship between environment and development in Asia with the establishment of theoretical and conceptual models, the initiation of principals, strategic framework, focus and advice for promoting the green development of Asia on the basis of summarizing Asia's advantages and disadvantages.

The synthesis report differs from other similar reports. It focuses more on the combination of theoretical and empirical research in the evolution of environment and development, on the combination of trends analysis in time series and comparative study at spatial scale, and on the combination of Asia's integrated analysis and regional and national differences. Besides, attempts have been made here on the innovative modeling of the evolutionary and theoretical relationship between environment and development, analysis of the driving forces in environmental evolution, and utilization of newly developed composite index to conduct empirical research of Asia's environment and development relation in the evolution.

We hope the reports will be of good value to the facilitation of the green development in Asia, providing advice on dealing with the shortage of conventional resources, environment pollution and climate change, fostering new economic growth and enhancing Asia's competitive advantages. This is the first time that AASA has ever undertaken such a study, and it surely leaves grounds for more detailed study and analysis of various issues and challenges that Asian countries face in the future.

The SDA project is sponsored by AASA. I want to give my special thanks to all AASA member academies for their consistent support, advice and assistance, without which, the accomplishment of such an internationally interdisciplinary scientific project would be impossible. My thanks also go to all the members in the working groups, especially Professors Namık Aras and Yi Wang, co-chairs of this study, without whom, efficiency and quality of the study would not be guaranteed. I also need to thank United Nations Environment Programme (UNEP), InterAcademy Council (IAC) and InterAcademy Panel (IAP) etc. for providing us the references and various advice and inspirations. Last but not the least, I want to express my thanks to all friends and the institutions that have rendered us encouragement and assistance all the way along.

The SDA project features with a wide range of fields and a huge amount of data, some of which are still in their early stage of development. Any comments or suggestions from our friends and various international institutions are warmly appreciated.

Prof. Jinghai Li

President

The Association of Academies of Sciences in Asia (AASA)

September 20, 2010

Preface

Diverse landscape and culture, dense population, rapid economic growth, world manufacturer center, …, those are all about Asia, the most economically dynamic region in the world. In the past two decades, most Asia countries have experienced major booming in industrial and agricultural production, along with fundamental changes in lifestyle and consumption patterns. While Asian countries produce more and higher quality products for world markets, more people than any other continent have walked out of the shadow of poverty. However, environmental change and deterioration are also highly evident as Asia regional economy continued to grow at a high rate. Under combined pressure of climatic change and human disturbances, the natural environment in Asia has been steadily degrading, which compromises the future development and the livelihood of its 3.8 billion residents. Meanwhile, share of Asian developing countries to global GHG emissions is rising rapidly. Impacts of climate change are especially visible in Asian various sectors including agriculture, forestry, biodiversity conservation, water resources, human health, air quality, energy security, etc. Impacts of climate change in Asia are already serious, and will very likely further worsen in future. Environmental sustainability is under serious threat.

This report of the Association of Academies of Sciences in Asia (AASA) aims to investigate the common environmental problems that threaten human livelihood and compromise sustainable future in Asia where we are in the same boat facing global climate change and environmental degradation. This report intends to provide governments and general public with up-to-date information on ongoing and future environmental changes, with guidelines of best practices of adaptation and mitigation by scaling-up of useful local and national experiences to regional level, and with regional overview/recommendations of environmental policies. It is designed to cover the entire continent, with four foci units: coastal Asia, dryland Asia, highland Asia, and urban Asia. The report of environment and climate change covers the following schemes:

• Environment states and trends: current situations and recent changes of key environmental issues and regional climate change over entire Asia, along with specific problems/solutions over the foci units.

• Best practices for environment improvement and climate change adaptation as scaling-up of useful local and national experiences to regional level.

• National and regional overview of environmental policies and recommendations for policy options for mitigating climate change and major environmental problems to achieve sustainability in Asia.

AASA Sustainable Development in Asia Project was established in 2007 to investigate common issues related to natural resources, energy, the environment and climate change, and culture from particular perspectives of agriculture. This report summarizes the key findings from the environment and climate change component of the project. It also reflects the outcomes of two AASA project workshops held in Beijing, China (February 2008) and İzmir, Turkey (September 2009) respectively.

Study Group on Environment and Climate Change

August 2010

Contents

Figures

Tables

Boxes

1 Environmental Issues in Asia: States and Trends

1.1 Key environmental issues in Asia: a big picture

In the past 2-3 decades, growth in industrial and agricultural production in Asian countries has created a miracle to the world. However, environmental deterioration has also been accelerated in the period. Under combined pressure of climatic change and human disturbances, the natural environment in Asia(Figure 1.1) has been steadily degrading, especially indicated by worsening urban traffic and air pollution, water pollution and scarcity, and land degradation. Poverty and lack of infrastructure are major challenges preventing Asia from improving environment, therefore, Asian developing countries, especially the least developed countries face the most critical challenges.

Figure 1.1 Geographic features and sub-regions of Asia, showing spatial coverage of this report (Image designed by Hao Gao & Gensuo Jia with ESRI and NASA data)

Air pollution, water pollution, and solid waste remain to be the fundamental and growing environmental issues across the continent. Municipal waste burdens are growing as incomes and thus consumption rise. Acid rain persists in East Asia and causes severe dieback and wildfires in natural forest, wastes from mineral extraction are accumulating in dryland areas and further threaten water supplies, and climate change processes are becoming more evident as air temperature steadily increases and extreme climate events such as heat wave, drought, rainstorm/flood become more frequent and intensified. Traditional and cultural attitudes to consumption and waste are rapidly changing as some societies and youth cultures enter the global consumption mainstream and urban centers expand.

Box 1.1 Atmospheric pollutants and greenhouse gases

The atmosphere is a thin shell of gases, particles and clouds surrounding the planet. It is in this thin shell that we are dumping several billion tons of pollutants each year. The major sources of this pollution include fossil fuel combustion for power generation and transportation; cooking with solid fuels; and burning of forests and woodland. The ultimate by-product of all forms of burning is the emission of carbon dioxide (CO_2), the key greenhouse gas. But there are also products of incomplete combustion, such as CO and NO_x, which can react with other gaseous species in the atmosphere. The net effect of these reactions is to produce ozone, another greenhouse gas. Energy consumption also leads to aerosol precursor gases (e.g., SO_2) and primary aerosols in the atmosphere, which have direct negative impacts on human health and ecosystems. Clean air is one of the basic requirements of human health and well-being. However, during the process of economic development, air pollution has been and continues to be a significant health hazard in Asia.

The new emerging economies of Asia developing countries are shouldering an increasingly greater share of regional and global environmental burdens. While global industrial production centers gradually moved into Asia, highly polluting industries are growing more rapidly in Asia developing countries than in regional developed countries. Some of the fastest growing industries in Asian developing countries are, in the absence of high corporate environmental performance and effective national pollution control policy, likely to produce relatively highly toxic waste. Hazardous waste production, management and trade are also growing challenges.

Rapidly expanding industries in Asia developing countries are often featured with high energy and water intensity. Fast-growing energy intensive industrial subsectors include the production of transport equipment, crude steel, chemicals, petroleum and rubber and plastic products. Water is an increasingly scarce resource in many countries, but the efficiency of water use, or water resources saving in the industrial sector have not been fully considered by the authorities and manufacturers.

The emission of air pollutants in a broad sense caused by human activity is a prime cause of climate change and the variation in atmospheric composition. These are increasingly becoming important issue concerning the global environment. Contribution of Asian countries on world CO_2 emissions has increased from 9% in 1973 to nearly 30% in 2009. Four of the eight largest carbon dioxide emitting countries (China, India, Japan, and Republic of Korea) are in Asia. Therefore, there is increasing pressure for low carbon development in Asia.

Changes of air pollution, water pollution, and land degradation in past decades are significant, and in most cases, the trends are worsening. Rapid industrial development with often low energy efficiency and steadily increases in urban traffic are major contributors to the worsening air pollution in Asia urban and coastal regions, while rivers and lakes are contaminated by pollutants and resource use from point and non-point sources. Inland regions, including central and west Asia, Mongolia, and western China are suffering from intensified land degradation, driven by both climate change and increasing human pressure on drylands.

Generally speaking, key environmental issues in Asia are identified as:

Air Pollution. Air pollution is probably the most serious problem in Asia developing countries, especially in major cities. The most familiar impact of the air pollution to the environment is particulate matters, sulfur dioxide, greenhouse gases, the ozone depletion substances, acid deposit, Asian brown cloud, and mercury pollution, etc. Most city dwellers in Asian developing countries are threatened by air pollution.

Water Crisis. Southeast Asia, East Asia, South Asia are facing unprecedented crisis of water resource in 2010. Because of the extreme weather conditions, the Mekong river basin, the sixth longest river in the world, unexpectedly faced the risk of the flow cutoff. The Asian Development Bank (ADB, 2007) recently projected that the developing countries in Asia may face even more serious water crisis in 10 years due to insufficient water resource management.

Biodiversity Declining. 2010 is the International Year of Biodiversity. Biodiversity is closely related to destiny of human in Asian countries, and therefore, we will have to face the problem of its declining together. Although Asia is rich in biodiversity, the biodiversity of Asia is facing unprecedented threat by the rapid economic development. Major threats include disappearing of primary forests, grassland degradation, loss of wildlife habitats, commercial harvesting of wild plants and animals, and landscape fragmentation. There were 12 species of endangered mollusks in Malaysia added to the red list of endangered species of International Union for Conservation of Nature (IUCN). Deforestation caused by commercial timber processing has threatened wildlife habitats in Asian tropical rain forests, and even mangrove. If current rate of deforestation continues to the end of the century, Southeast Asia will lose 3/4 of the forests and hundreds of rare species of vascular plants, mammals and birds.

Municipal waste and illegal transboundary movement of waste. Environment problem stemming from waste has already become the main obstacle for the sustainable development of Asian countries. While the production and disposition of waste in Asian cities remain unresolved, the major economies in Asia such as China, India and ASEAN countries have become the destinations of illegal transboundary movement of waste. Especially, air and water pollution caused by illegal transboundary movement of electronics garbage is becoming a serious problem in many Asian countries. Many Asian developing countries are becoming a key destination of international electronic waste.

Desertification and Sandstorm. From the eroded hill in Nepal to expanding desert in China, India and Pakistan, the land deterioration caused by climate change and human activities in Asia is serious than any other continents. Most arid and semi-arid regions in Asia are facing the desertification and becoming main sources of dust storms. According to the report of China Meteorological Bureau, the total amount of dust of Asia approximately reaches 800 million tons per year. It is approximately half of global dust releasing. The countries deeply affected by dust have started to take actions. The projects of sandstorm in the Tripartite Environment Ministers Meeting (TEMM) and North-East Asian Subregional Programme for Environmental Cooperation (NEASPEC) are among the most important regional cooperation.

Marine Environment. Marine pollution from land-based sources has become a major environmental problem in Asia. Because 90% of the sewage is not processed and directly dumped into sea, marine environment is worsening and the coastal fishing industries have been affected. Land-based impacts, such as unprocessed sewage, soil erosion and sediment down stream transport, increasing use of pesticide, and the development in coastal areas are among the main threats to marine environments.

1.2 Atmosphere

As mentioned above, atmosphere and water quality are the most important environmental issues at regional scale in Asia. In the past 10-30 years rapid economic growth and industrialization in most Asian countries have damp millions of tons of various pollutants into atmosphere and water bodies. Those pollutants are often redistributed over the regions by circulations and river flows and become regional problems.

Urban and densely populated areas are often blamed as major sources of environmental pollution. More than half of the world's population live in urban areas in Asia. Urban air pollution in most Asian mega-cities (with a population of more than ten million) such as Beijing, Delhi and Jakarta has worsened due to the cumulative effects of population growth, industrialization and increased vehicle use. The health consequences of exposure to polluted air are considerable-approximately 20—30 percent of all respiratory diseases appear to be caused by air pollution.

The exposure of human and environment to air pollution becomes an important challenge and it is also a global public health problem. The most familiar impact of the air pollution to the environment is particulate matters, sulfur dioxide, greenhouse gases, the ozone depletion substances, acid deposit, Asian brown cloud, and mercury pollution, etc. (Figure 1.2) Many people in Asia still suffer from serious air pollutants.

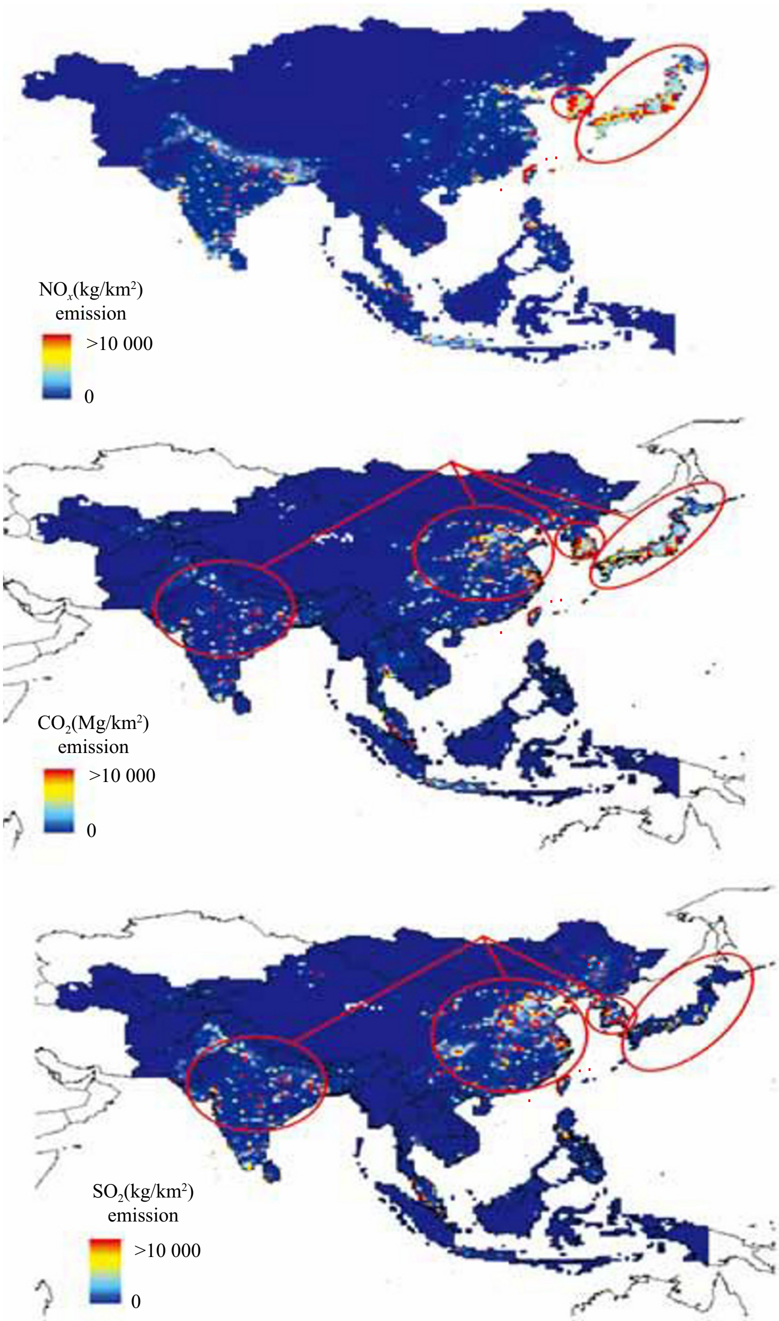


Figure 1.2 Emissions of NO_X, sulfur dioxide, and carbon dioxide from Asia countries (Source: Kawase, 2007)

1.2.1 $PM_{2.5}$

Particles less than 2.5 micrometers in diameter ($PM_{2.5}$) are referred to as "fine" particles and are believed to pose the greatest health risks. Because of their small size fine particles can lodge deeply into the lungs. Particulate matter, or PM, is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that individually they can only be detected with an electron microscope.

Sources of fine particles include all types of combustion activities (motor vehicles, power plants, wood burning, etc.) and certain industrial processes. Other particles may be formed in the air from the chemical change of gases. They are indirectly formed when gases from burning fuels react with sunlight and water vapor. These can result from fuel combustion in motor vehicles, at power plants, and in other industrial processes.

One group at high risk is active children because they often spend a lot of time playing outdoors and their bodies are still developing. In addition, oftentimes the elderly population is at risk. People of all ages who are active outdoors are at increased risk because, during physical activity, $PM_{2.5}$ penetrates deeper into the parts of the lungs that are more vulnerable to injury.

In China, $PM_{2.5}$ has not been incorporated into the monitoring index system. But it has raised attention of the government. When determining the monitoring index of atmospheric environment and control target of main atmospheric pollutants, the government makes great effort to improve the accuracy and rationality. Now some cities such as Chongqing, Qingdao added the monitoring of $PM_{2.5}$.

1.2.2 PM_{10} or respirable particulate matter

At present, the most frequently used indicator for suspended particles in the air is PM_{10} (particles with an aerodynamic diameter <10 μm). An overview of typical annual average PM_{10} concentrations in selected cities in Asia countries are presented in Figure 1.3. The data from those major cities demonstrated that the general levels of suspended particles in Asia are relatively high. The annual average PM_{10} concentrations in the selected Asian cities ranged from about 35 $\mu g/m^3$ to 220 $\mu g/m^3$, while in Europe and North America the typical range of annual average PM_{10} concentrations was 15-60 $\mu g/m^3$ (World Health Organization, 2006).

At regional scale, the highest concentrations of PM_{10} were reported from Asia (World Health Organization, 2006). This region also experiences relatively high background concentrations owing to forest fires and local emissions of particles from the use of low-quality fuels. A well-known springtime meteorological phenomenon throughout East Asia, causing the Asian dust cloud, originates from windblown dust from the deserts of Mongolia and China and adds to the

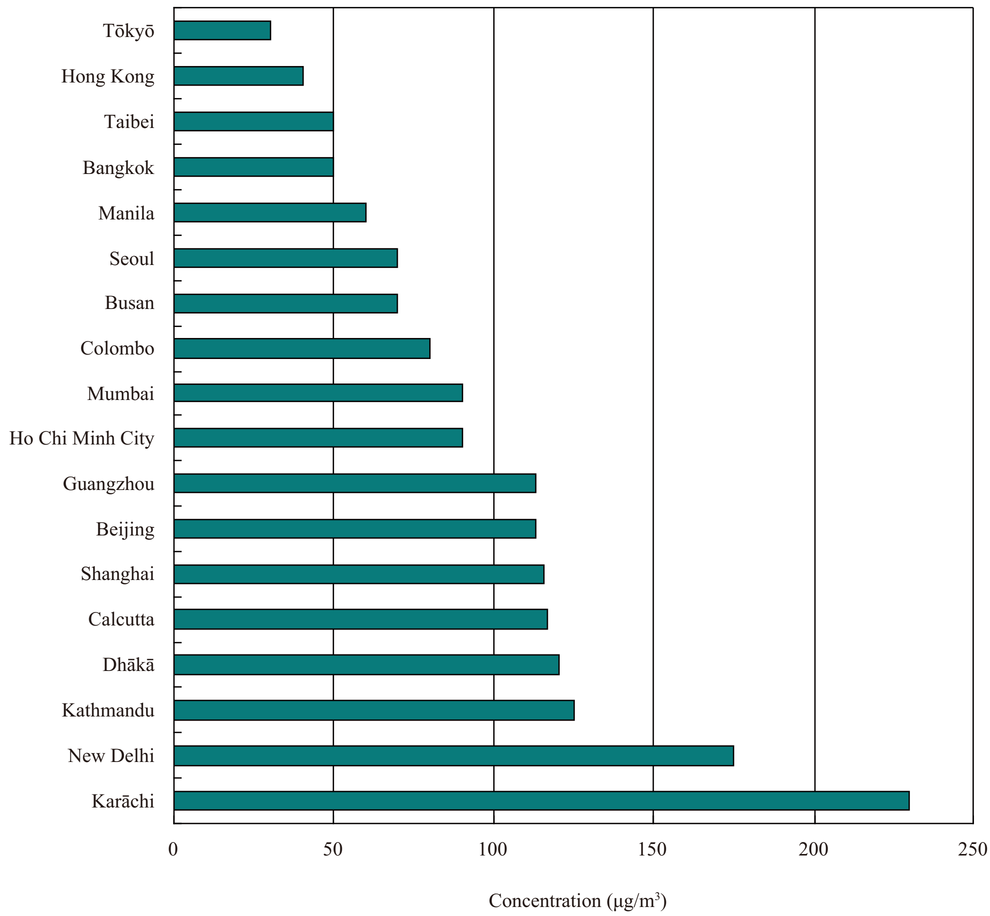


Figure 1.3 Annual average PM_{10} concentrations observed in selected cities of Asia (Source: WHO, 2006)

general level of PM_{10} in the region. Many Asian cities experience very high air-borne particle concentrations due to primary particles emitted from coal and biomass combustion and motor vehicle exhaust, as well as secondary sulfates formed by atmospheric chemical reaction from the sulfur dioxide emitted from coal burning.

1.2.3 Sulfur dioxide

Due to decade-long international efforts, levels of sulfur dioxide have decreased markedly in most of Europe and North America and in many locations in Asia as well. The improvement in many Asia countries in the last few decades has been driven by various national and international regulations, including the Protocols under the Convention on Long-range Transboundary Air Pollution.

An overview of typical annual average sulfur dioxide concentrations reported from selected cities of Asia, based on data from 2000-2005, is presented in Figure 1.4. About half of the cities had annual average concentrations of sulfur dioxide over 20 $\mu g/m^3$, while about 15% of the cities exceeded a level of 50$\mu g/m^3$ (World Health Organization, 2006).

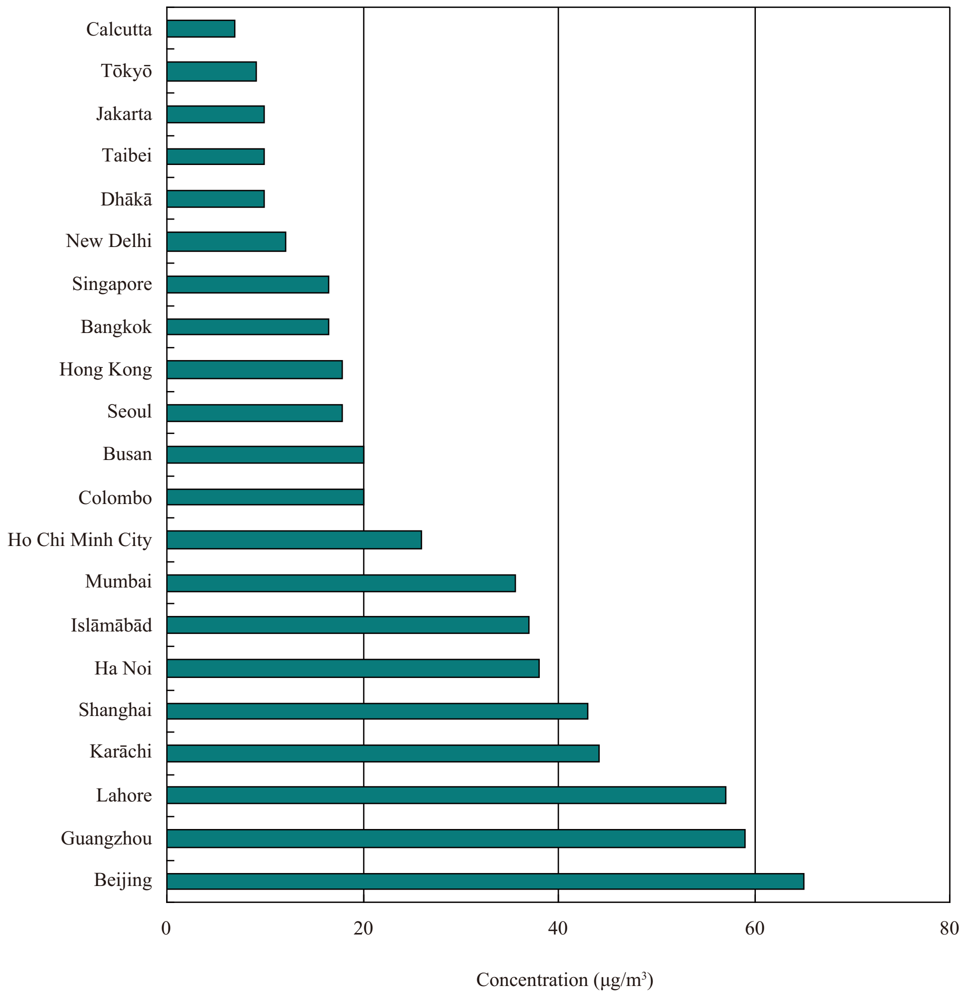


Figure 1.4 Annual average sulfur dioxide concentrations in 2000-2005 reported from selected cities of Asia (Source: WHO, 2006)

The highest sulfur dioxide concentrations were recorded in some of the megacities in Asia developing countries, although some large urban areas have fairly low concentrations. In February 2005, New Delhi reported weekly average concentrations of 5-10μg/m^3, while Jakarta reported between 4 μg/m^3 and 24 μg/m^3 (Sofyan et al., 2005). Sulfur dioxide levels that are already high in some cities of Asia may increase further, largely related to use of coal as main energy source. Sulfur dioxide pollutant concentrations are generally higher in northern Chinese cities than in the south. The average sulfur dioxide concentration in 2002 was 5 2μg/m^3 (Hao and Wang, 2005). The national average sulfur dioxide concentration in 2004 was 43 μg/m^3, and 22% of cities recorded annual average concentrations above 60μg/m^3. While typical annual average concentrations of sulfur dioxide in urban areas in developing countries were 40-80 μg/m^3, the levels in North America and Europe were 10-30μg/m^3 in recent decades.

1.2.4 Nitrogen dioxide

The principal sources of nitrogen dioxide are traffic and to a lesser extent industry, shipping and households. High nitrogen dioxide levels, combined with ultrafine particles and other oxidants, have become one of the major air pollution problems in urban areas all over the world. Nitrogen oxides are one of the main components of the mixture of pollutants classically referred to as "photochemical smog".

Rural background concentrations of nitrogen dioxide in industrialized countries have been measured at around 15-30 μg/m^3. In the past five years, nitrogen dioxide concentrations exceeded 40 μg/m^3 over many of the large cities in Asia. Short-term nitrogen dioxide concentrations may vary considerably within cities and from time to time during the day and night. Also, average concentrations depend on the distance of the measurement site from main roads. Figure 1.5 summarizes the annual average nitrogen dioxide concentrations measured in selected cities in Asia.

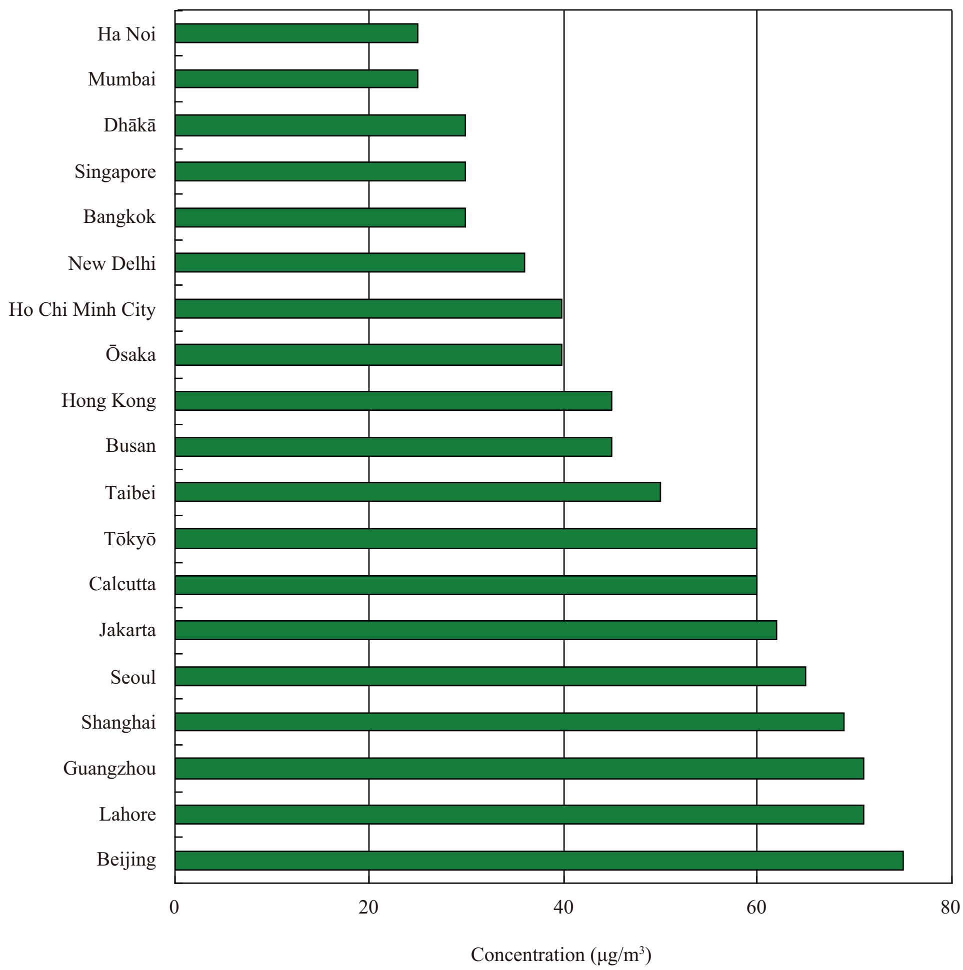


Figure 1.5 Annual average nitrogen dioxide concentrations in 2000-2005 reported from selected cities of Asia (Source: WHO, 2006)

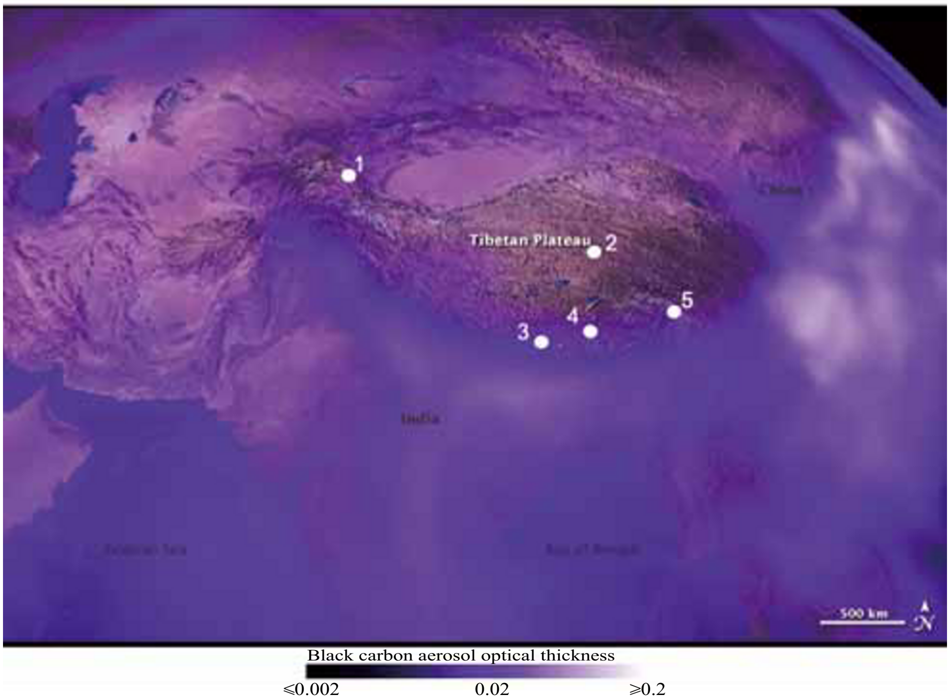
Annual average nitrogen dioxide concentrations in Asian cities typically lie in the range 23-74μg/m^3. In 2002, the average concentration in Calcutta was 77μg/m^3 and in New Delhi was 49μg/m^3 (World Bank, 2005). Typical concentrations measured in New Delhi in February 2005 were 31-83μg/m^3. In Jakarta, average nitrogen dioxide concentration mapped using passive samplers showed levels of 20-70 μg/m^3 as a weekly average (Sofyan et al., 2005). The peak daily concentration was 446 μg/m^3.

1.2.5 Asian brown cloud

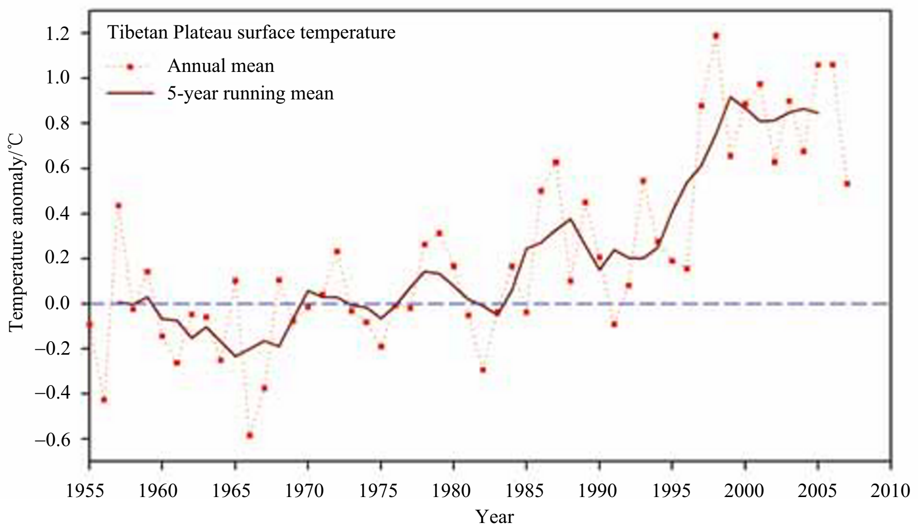
Asian brown cloud is a layer of air pollution that appears as a giant brown stain hanging in the air over parts of South Asia, namely the northern Indian Ocean, India, and Pakistan every spring. It refers to plums of brown haze about three kilometers thick, an area of about 1,000 square kilometers was first discovered in early 1990s over the region. It is created by a range of airborne particles and pollutants from combustion (e.g. wildfire, traffic, and factories), biomass burning and industrial processes with incomplete burning (Gustafsson et al., 2009). Its main components are carbon aerosols, sulfate, nitrate, organic particles, fly ash and mineral grains, high concentrations of carbon monoxide and various organic sulfur dioxide, gas compounds, etc.

The brown cloud is accumulated by the vehicle exhaust and industrial pollution in some big cities of South Asia, the forest fires and millions of inefficient cooker burning wood or cow muck in Indonesia and increasing pollution (Ramanathan, 2003). Atmospheric pollutants which are often gathered over tens of thousands, hundreds of thousands of area of square kilometers in China's north district, Yangtze River delta and Pearl River delta and Sichuan basin, etc., are similar to atmospheric brown cloud. Such formation of massive pollutant is closely related with weather and emission of atmospheric pollutants. Asian brown cloud is associated with the winter monsoon (November/December to April) during which there is no rain to wash pollutants from the air. It is hardly to be ignored for it is a serious threat to the air quality of Asia.

The major impacts of Asia brown cloud include threats on human health, Changes of rainfall patterns with the Asian monsoon, increase in rainfall over certain areas, retreat of the Hindu Kush-Himalayan glaciers and snow packs, and decrease of crop harvests (Ramanathan et al., 2005; Ramanathan, 2008). Meanwhile, the brown clouds may have masked 20-80 percent of greenhouse gas forcing in the past century (Ramanathan, 2008). Clouds of pollution over the Indian Ocean appear to cause as much warming as greenhouse gases released by human activities. The comprehensive function of greenhouse gases and atmospheric brown cloud is claimed as the main reason for melting of Himalayan glaciers in the past fifty years (UNEP, 2007; Xu et al., 2009) (Figure 1.6).



(a) Atmospheric black carbon aerosol optical depth



(b) Amplitudes of climate warming above 4,000m on the Plateau

Figure 1.6 Asian brown cloud has accelerated melting of alpine glaciers on the Tibetan Plateau (Source: Xu et al., 2009)

1.2.6 Acid deposit

Industry oriented acid deposit is another major environmental problem in Asia, especially in East Asia. East Asia is vast and characterized by considerable contrasts and differences. The regional geography and climatology have a substantial influence on the spatial and temporal distribution of acid deposition. Precipitation in the entire region is influenced by the Asian monsoon, which causes alternating dry and rainy seasons in the subtropical and temperate regions. Tropical cyclones and typhoons also deliver a large amount of precipitation to these regions, mainly in summer and autumn.

Atmospheric arid deposition consists of both wet and dry components. In wet deposition, sulfuric acid and nitric acid were identified as the major acidifying species. Figure 1.7 shows the trend of annual pH of precipitation (2000-2007) at the monitoring sites in EANET countries, including Cambodia, China, Indonesia, Japan, Laos, Malaysia, Mongolia, Myanmar, Philippine, Republic of Korea, Russia, Thailand, and Vietnam. The lowest pH values observed were comparable with those in Europe and North America.

Figure 1.7 Trend of annual pH of precipitation (2000-2007) (Source: Second EANET Report for Policy Makers: Clean Air for A Sustainable Future, 2009)

Figure 1.8 shows the mean annual values of wet deposition of sulfate and nitrate ions from 2000 to 2007 at the same sites. Some sites in China receive high deposition of sulfate ions with relatively low precipitation amounts. High deposition of sulfate ion was also detected at several sites in Japan, Indonesia, Malaysia and the Philippines, but this was mainly due to the large amounts of precipitation. Large amounts of nitrate ions are deposited at the urban sites of Southeast Asia. Their annual deposition rates ranged widely reflecting the difference in precipitation in the region. The lowest levels of deposition were at remote sites in Mongolia, Russia Far East, Thailand and Japan, due to either low atmospheric concentrations or low precipitation levels.

The annual deposition rates of ammonium ions varied widely depending on the precipitation rate. Large deposition fluxes were observed in the northern

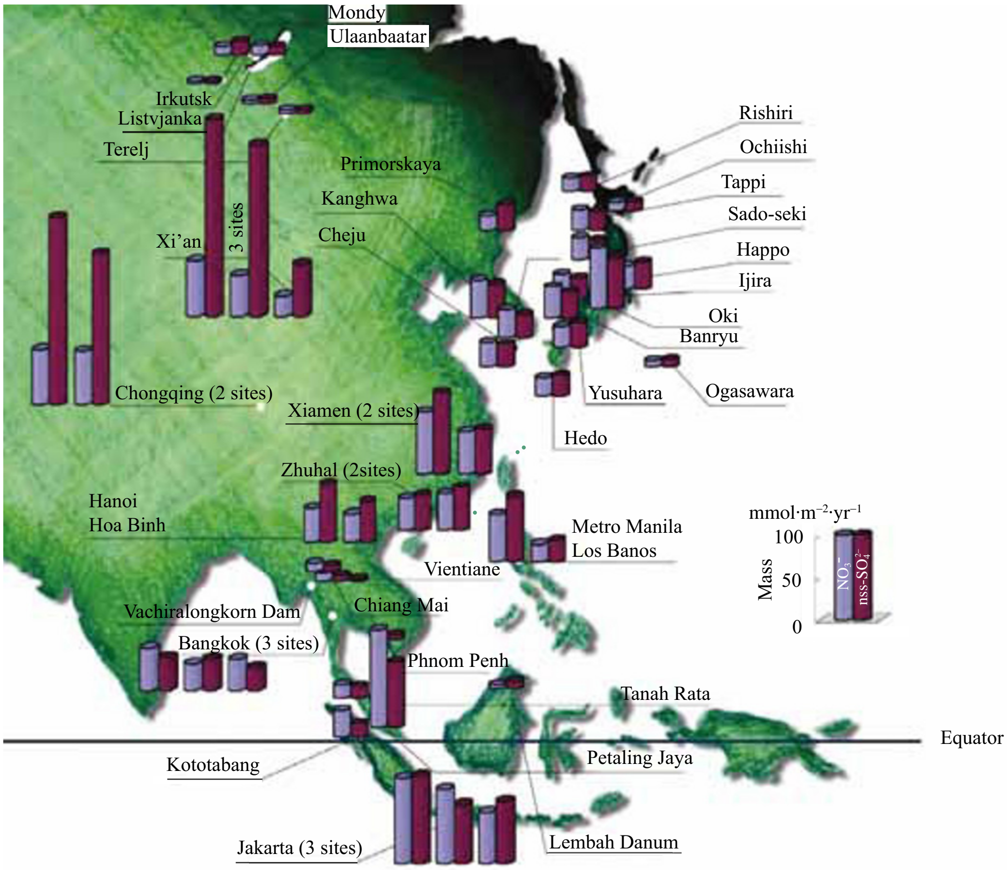


Figure 1.8 Distribution of average annual wet deposition of nss-SO_4^{2-} and NO_3^- for 2000-2007 (Source: Second EANET Report for Policy Makers: Clean Air for a Sustainable Future, 2009)

part of China due to their high concentrations in soil dust, followed by Southeast Asia, while low deposition rates were observed at sites in Russia Far East and Japan.

The amount of dry deposition is generally considered to be about the same level as that of wet deposition although it sometimes exceeds wet deposition levels, for example in arid and semi-arid areas. Air concentrations of sulfur dioxide ranged widely with higher concentrations found in or near the urban areas. The concentrations of gaseous nitric acid and nitrate particles were also higher at rural and urban areas than at remote sites.

1.3 Water

1.3.1 Water shortage

Comprising over 70% of the Earth surface, water is undoubtedly the most precious natural resource that exists on our planet. Equitable and sustainable management of water resources is a major global challenge. About one third of the world's population lives in countries with moderate to high water stress with disproportionately high impacts on the poor. With current projected human population growth, industrial development and the expansion of irrigated agriculture in the next two decades, water demand will rise to levels that will make the task of providing water for human sustenance more difficult (Asia Society Leadership Group on Water Security, 2009).

Take the South Asian as an example. The South Asian countries are home to about one-fourth of the world population, but only contain about 4.5 percent (1,945 billion m^3) of the world annual renewable water resources(43,659 billion m^3). Except for Bhutan and Nepal, the percapita water availability in the region is less than the world average, with water use in this region being limited mainly to the agriculture sector. Almost 95 percent of the withdrawn water is consumed by the agriculture sector, a much larger proportion than the average global agricultural water use (70 percent). In contrast, the region generally exhibits very limited water use in the industrial and domestic sectors. The percentage of the population with sustainable access to improved sanitation facilities in South Asia is 39 percent (compared to the world average of 59 percent) (Babel and Wahid, 2008).

Climate change is likely to increase the frequency of extreme events like droughts and floods (Solomon et al., 2007) and introduce high levels of risks and uncertainties that the water industry may not be able to handle with confidence. Asian surface and underground water supplies are quickly exploited from feverish economic growth and a population of 3.8 billion. In recent years economic and social development have led to increasing water demand, and with the impact of global warming, drought and water scarcity are increasingly frequent. Drought ass already caused loss of agricultural yields and properties for many farmers, especially in semi-arid areas.

Agriculture is by far the biggest water user. The expansion of hydropower generation and irrigated agriculture, now happening mostly in developing countries, is vital for economic development and food production. However, the consequent changes in river flow and groundwater table have major negative impacts on freshwater and coastal ecosystems, as well as long-term water supply (ADB and Asia-Pacific Water Forum, 2007).

In addition to agricultural demands, pressures on water resources are compounded by physical alteration and destruction of wetland habitats, largely driven by urban and industrial development. Invasive species introduced to water bodies intentionally or inadvertently are also major concerns.

Modifications of the water cycle through irrigation works and water supply schemes have benefited society for centuries. However, the global impacts of human interventions in the water cycle, such as land use modification, urbanization, industrialization and water resources development, are likely to surpass those of recent or anticipated climate change, at least over next 2-3 decades.

1.3.2 Water pollution

Many Asia inland rivers and lakes as well as coastal water are seriously contaminated by pollutants from point and non-point sources. Point sources of pollution occur when harmful substances are emitted directly into a body of water. A nonpoint source delivers pollutants indirectly through environmental changes. Water pollution in Asian countries is largely caused by domestic sewage but is compounded by industrial wastes. Contamination of available water is a major health threat (Asia Society Leadership Group on Water Security, 2009). Comprehensive water resource management will be one of the most difficult issues in Asia in coming years. Such an approach must encompass water demands from industrial and agricultural as well as urban use. But unfortunately, Water quality management has mostly been a neglected issue in Asian developing countries. Wastewater collected from cities is often discharged to nearby rivers, lakes or oceans with little or no treatment, which heavily contaminates water bodies around urban centers and is already causing health and environmental problems.

The water crisis in Asia has caused hundreds of millions of people live without safe drinking water in this region. Because many developing countries within the area are short of necessary infrastructure and environmental management means, about half of people lack health facilities. While population increasing, quick urbanization, climate change and many other factors, bring the deterioration of water environmental quality.

One contributing factor to water crisis is massive and rapid urbanization (Reddy and Behera, 2006), such as that seen in megacities like Beijing, Dhākā, Jakarta, and Karāchi. Asia water scarcity will likely worsen with global warming in coming decades. Although groundwater resources are generally abundant and relatively safe for domestic purposes, depletion of groundwater resources has been an increasing problem in Asia (Figure 1.9). Uncontrolled timber harvest, mining, and mineral extraction for building materials are contaminating downstream water courses and aquifers. To make the situation even worse, most solid waste disposal and landfill sites in Asian developing countries are poorly operated and maintained, causing leaching of pollutants into streams and groundwater.

Human activities at watershed scales cause increased water-borne pollution from point and non-point sources, affecting inland and coastal aquatic ecosystems. The non-point sources are more difficult to identify, quantify and manage. Agricultural run-off containing nutrients and agrochemicals is the main source of water pollutants in many countries. Domestic and industrial effluents are also major sources, as inadequately treated wastewater discharged directly into waterways in many developing countries. Virtually all industrial activities generate water pollutants, for example, unsustainable forestry, mining, waste disposal, and aquaculture.

(a) Declining surface water supply along irrigation canals in western Inner Mongolia, China

(b) Water pollution near Vladivostok, Russia

Figure 1.9 Water shortage and pollution in Asia (Photo credit: Gensuo Jia)

1.3.3 Wetland ecosystems

Since nearly all industrial and manufacturing activities require adequate water supplies, this situation is likely to impede socio-economic development, and increase pressures on freshwater ecosystems. At the global scale, the integrity of aquatic ecosystems—the state of their physical elements, their biodiversity and their processes—continues to decline (UNEP, 2007), reducing their capacity to provide clean freshwater, food and other services such as contaminant attenuation, and to buffer against extreme climatic events.

From coastal swamps to inland floodplains, Asia has lost its wetlands rapidly in past decades, and these fragile ecosystems continue to lose ground in the region. A principal cause of wetland loss is the draining or filling for human settlements and agriculture. In Asia, where some 85 percent of the wetlands of international importance are threatened, rice cultivation has claimed 40 million hectares in the central plains of India and significant portions of natural wetland areas in Thailand, Viet Nam, and China (Rāmsar Convention Bureau, 2003).

1.4 Regional climate change

Recent reports from the Intergovernmental Panel on Climate Change (2007) confirm that climate change is occurring at a larger and more rapid rate of change than was thought likely only six years ago. Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56, 0.92]°C is larger than the corresponding trend of 0.6 [0.4, 0.8]°C (1901-2000) given in the Third Assessment Report (TAR). The temperature increase is widespread over the globe and is greater at higher northern latitudes. Land regions have warmed faster than the oceans, and Asia experienced highest rate of warming among all continents. Temperatures are increasing, and higher associated rates of evaporation will bring drier conditions, especially in dryland regions where ecosystems and social-economy are under pressure of water deficit.

Asia societies are critically dependent on the variability of the monsoon circulation system, and therefore, sensitive to major changes in monsoon system. The greatest increases of temperature in past century have been recorded in Asia, a number greater than any other continents. This is likely driven by combination of global forces and regional land surface processes.

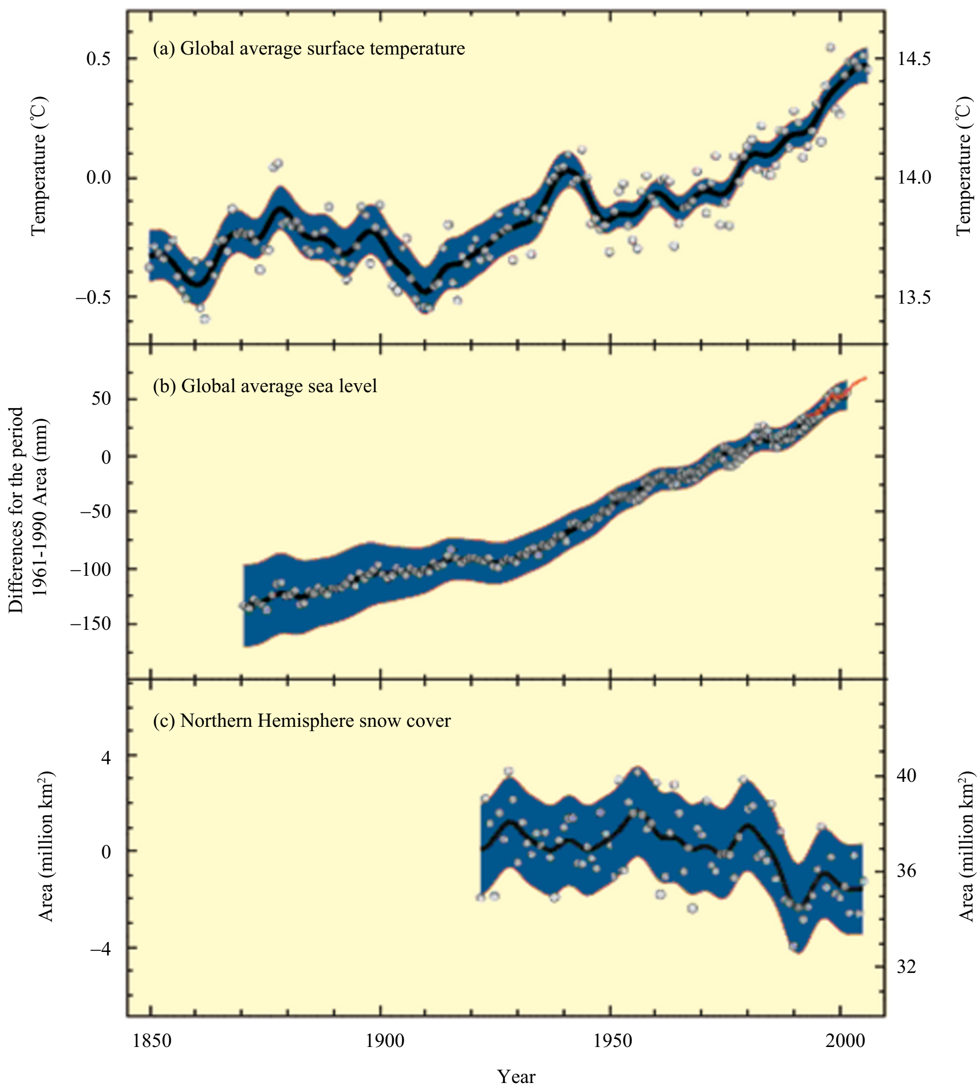


Figure 1.10 Changes in temperature, sea level and Northern Hemisphere snow cover. Observed changes in: (a) global average surface temperature; (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values (Source: Solomon et al., 2007)

The best available scientific knowledge (via numerical models) indicates that global warming will significantly affect the variability of the Asia monsoon system, especially the hydrological components. There are recent indications that anthropogenic impacts caused by enhanced greenhouse gas emissions and large-scale changes in land cover might be responsible for regional climate change in Asia, featured with attenuation of surface heating, declining crop production, and changes in precipitation.

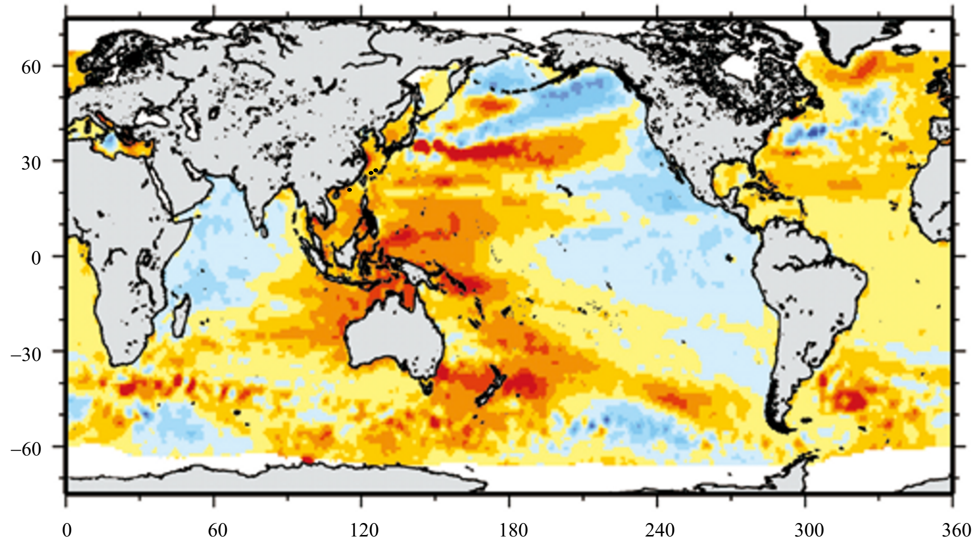
Rising sea level is consistent with warming (Figure 1.10). Global average sea level has risen since 1961 at an average rate of 1.8 [1.3, 2.3] mm/yr and since 1993 at 3.1[2.4, 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear. However, observed sea level rise is not homogeneous around the globe, while western and southwestern Pacific are among the greatest in terms of linear trends of sea level and thermal expansion (Figure 1.11).

Observed decreases in snow and ice extent are also consistent with warming. Mountain glaciers and snow cover on average have declined in both hemispheres. In Asia, however, there is a largely mixed picture on the climate induced changes of alpine glaciers. Scientists for the most part agree glaciers are melting at an accelerated rate as temperatures increase, especially at lower altitudes and edge of glaciers. However, there are recent evidents that some glaciers over 6,000m in Himalayas are actually expanding, and those glaciers could hold out for centuries in a warmer world (Hewitt, 2005).

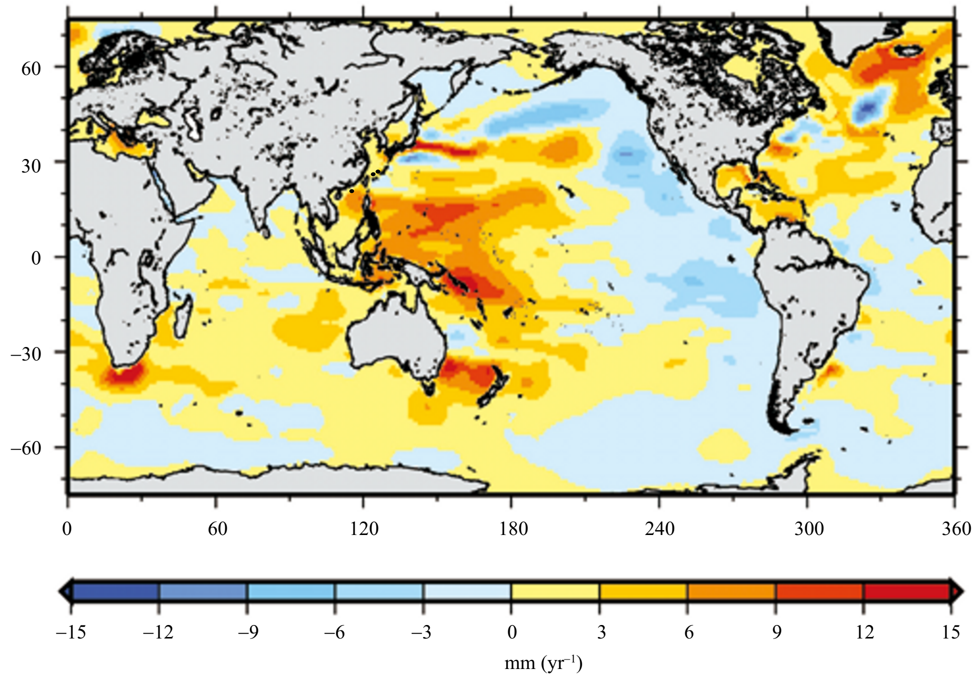
Meanwhile, there is a highly mixed picture on variability of precipitation at regional scale. From 1900 to 2005, precipitation increased significantly in northern and central Asia but declined in parts of southern Asia. The area affected by drought has likely increased since the 1970s throughout Asia, particularly in central and East Asia. In semi-arid East Asia, decade-long trend of aridification or water deficit have been detected by both meteorological records and satellite data (Ma and Fu, 2003).

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system. Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004 (Solomon et al., 2007). The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000. Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. During the past 50 years, the sum of solar and volcanic forcing would likely have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcing.



(a) Geographic distribution of short-term linear trends in mean sea level (mm · yr⁻¹) for 1993 to 2003 based on TOPEX/Poseidon satellite altimetry (updated from Cazenave and Nerem, 2004)



(b) geographic distribution of linear trends in thermal expansion (mm · yr⁻¹) for 1993 to 2003 (based on temperature data down to 700 m from Ishii et al., 2006)

Figure 1.11 Global sea level and thermal expansion from 1993-2003
(Source: Solomon et al., 2007)

Meanwhile, Share of Asian countries to global GHG emissions is rising rapidly. Share of Asian developing countries to global GHG emissions is rising rapidly. By 2010, four of the eight largest carbon dioxide emitting countries (China, India, Japan, Republic of Korea) are in Asia. There is increasing pressure for low carbon development in Asia, although Per Capita emissions of carbon dioxide from fossil fuel combustion of above Asia countries are still much lower than that from most industrialized countries such as US, Canada, and Australia (Figure 1.12).

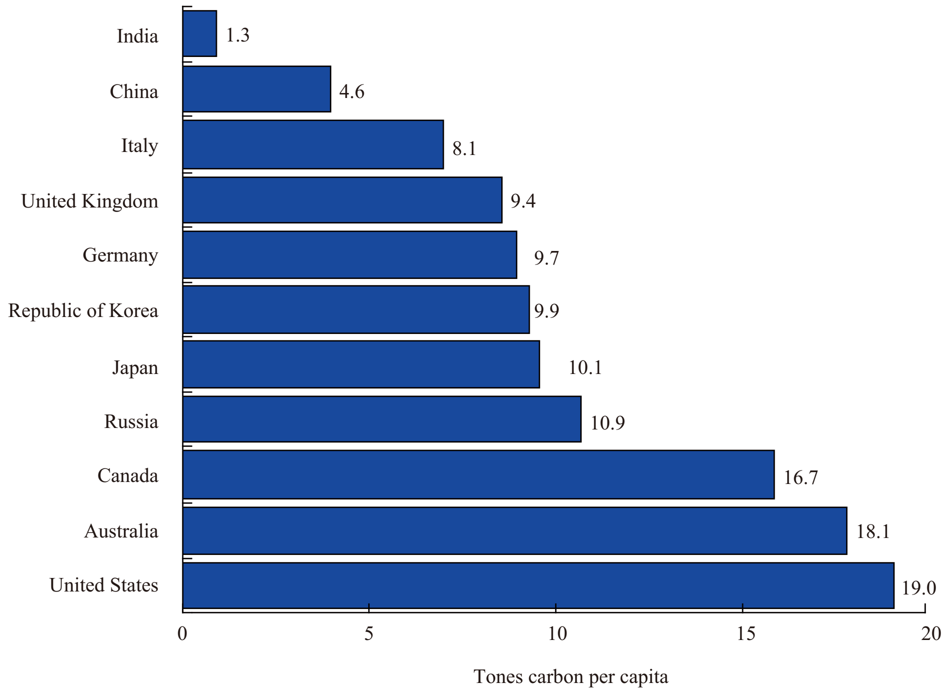


Figure 1.12 Per capita emissions of carbon dioxide over selected countries in 2006 (Source: IEA, 2009)

The projected and current impacts of climate change on this continent are rather complicated and sometimes confused. While most model projections based on IPCC climate change scenarios suggested largely negative impacts by 2100, observation data over past 2-3 decades indicated mixed signals—the major impacts of climate change varies greatly among subregions and sectors over this diverse continent; often negative on one place or sector, but positive on another place or sector. For example, it is widely believed that warming leads to declining of food supply, however, agriculture in current cold regions will likely get benefit from warming. Also, increases in precipitation have been observed in Asia arid regions, in contrast to increasing drought in semi-arid regions. Here we summarize possible negative and positive impacts of climate change on different sectors of Asia countries (Table 1.1).

Likely negative impacts of climate change on Asia countries:

- Increases in extreme weather events and consequent natural disasters, especially floods, typhoon, drought, heat wave, and wildfire;
- Threat crop production and agriculture, and therefore affect sustainable food supply;
- Increased risk of vector borne diseases, such as malaria and dengue fever;

• Widespread damage of natural ecosystems and loss of biodiversity;

• Changing marine productivity, influenced by coral bleaching and impacts on mangroves and sea grass beds;

• Retreats of mountain glaciers and permafrost and changes in watershed hydrology;

• Changing hydrological regimes and increases winter flooding, but decreases summer flow, along with more frequent and intense drought in semiarid regions;

• More severe water shortage and energy demands over urban and agricultural areas due to warming and instability in water supply;

• Continuous deteriorations of environmental quality and land degradation.

Possible positive impacts of climate change on Asia countries:

(1) Drop in energy demands for winter heating and agricultural greenhouse maintenances;

(2) Increases in agricultural productivities in high altitude and high latitude areas, such as northeast Asia and the Tibetan Plateau;

(3) Expansions in ice-free periods of northwest Pacific and major rivers in northern Asia, and therefore beneficial to voyage;

(4) Likely greening in Gobi and desert areas in West Asia, Central Asia, China, and Mongolia due to increases in precipitation in recent decade.

Table 1.1 Summary of key observed past and present climate trends and variability in Asia

Region	Country	Change in temperature	Change in precipitation
North Asia	Russia	2 to 3°C rise in past 90 years, more pronounced in spring and winter	Highly variable, decrease during 1951 to 1995, increase in last decade
	Mongolia	1.8°C rise in last 60 years, most pronounced in winter	7.5% decrease in summer and 9% increase in winter
Central Asia	Regional mean	1 to 2°C rise in temperature per century per century	No clear trend during 1900 to 1996
	North- West China	0.7°C increase in mean annual temperature from 1961 to 2000	Between 22% and 33% increase in rainfall
Tibetan Plateau	Regional mean	0.16 and 0.32°C per decade increase in annual and winter temperatures, respectively	Generally increasing in north- east region

Continued

Region	Country	Change in temperature	Change in precipitation
West Asia (Middle East)	Iran	During 1951 to 2003 several stations in different climato- logical zones of Iran reported significant decrease in frost days due to rise in surface temperature	Some stations show a decreasing trend in precipitation (Anzali, Tabriz, Zahedan) while others (Mashad, Shiraz) have reported increasing trends
East Asia	China	Warming during last 50 years, more pronounced in winter than summer, rate of increase more pronounced in minimum than in maximum temperature	Annual rain declined in past decade in North-East and North China, increase in Western China, Changjiang River and along south- east coast
	Japan	About 1.0°C rise in 20th century, 2 to 3°C rise in large cities	No significant trend in the 20th century although fluctuations increased
	Korea	0.23°C rise in annual mean temperature per decade, increase in diurnal range	More frequent heavy rain in recent years
South Asia	India	0.68°C increase per century, increasing trends in annual mean temperature, warming more pronounced during post monsoon and winter	Increase in extreme rains in north- west during summer monsoon in recent decades, lower number of rainy days along east coast
	Nepal	0.09°C per year in Himalayas and 0.04°C in Terai region, more in winter	No distinct long- term trends in precipitation records for 1948 to 1994
	Pakistan	0.6 to 1.0°C rise in mean temperature in coastal areas since early 1900s	10 to 15% decrease in coastal belt and hyper arid plains, increase in summer and winter precipitation over the last 40 years in northern Pakistan
	Bangladesh	An increasing trend of about 1°C in May and 0.5°C in November during the 14 year period from 1985 to 1998	Decadal rain anomalies above long term averages since 1960s
	Sri Lanka	0.016°C increase per year between 1961 to 90 over entire country, 2°C increase per year in central highlands	Increase trend in February and decrease trend in June

Continued

Region	Country	Change in temperature	Change in precipitation
Southeast Asia	General	0.1 to 0.3°C increase per decade reported between 1951 to 2000	Decreasing trend between 1961 and 1998. Number of rainy days have declined throughout S-E Asia
	Indonesia	Homogeneous temperature data were not available	Decline in rainfall in southern and increase in northern region
	Philippines	Increase in mean annual, maximum and minimum temperatures by 0.14°C between 1971 to 2000	Increase in annual mean rainfall since 1980s and in number of rainy days since 1990s, increase in interannual variability of onset of rainfall

Source:
Cruz et al., 2007

Asia developed countries in the higher latitudes are expected to experience a greater change in climate than those in tropical developing countries. Yet the vulnerability of tropical developing countries is likely to be much greater, due to their lower level of adaptive capacity. Where people have financial resources, access to technology, high levels of education and training, good health, security, strong institutions and effective organizations, they can more adequately cope with exogenous changes, shocks, and impacts. Where these attributes of adaptive capacity are low, vulnerability is correspondingly greater.

There is much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. The IPCC Special Report on Emissions Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25% to 90% (CO_2-eq) between 2000 and 2030, with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond.

For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant on the levels of 2000, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios (IPCC, 2007). Anthropogenic warming rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilized.

For future climate projection, there are great uncertainties due to complexity of climate system and the limitation of existed climate models. For example, IPCC projected climate warming by 2100 ranges from 1.8°C-4.5°C even with over 20 best global climate models. Nevertheless, no matter how significant the warming trends are, extreme climate events are becoming more frequent and intensified over years in the world and in Asia.

1.5 Climate extremes and natural disasters

Climate extremes and related natural disasters cause major loss of life and damage to infrastructure and impact on future growth prospects. More than 70 percent of all disasters globally occurred in Asia, but insufficient investment has been made to prepare for and mitigate such disasters.

The most recent extreme events include record high temperature and hot wave in many Indian cities in June 2010, extreme heavy rainstorms and floods along China's Yangzi River in summer 2010, severe drought in normally water abundant southwest China in spring 2010, record low spring temperature in North China in 2010, series severe typhoon in southeast Asia in summer 2009, and rare snow storm throughout East Asia in March 2008 (Figure 1.13).

Asian is the most disaster-prone region in the world, accounting for more than 70 percent of all natural disasters worldwide and more than 80 percent of deaths from natural disasters in past hundred years (UNEP, 2005). Among the most destructive and frequent hazards caused by extreme climate events have been flash floods, storm surges, droughts, and wildfire. Prolonged droughts in South Asia have compromised food security and caused widespread famine and food shortages. Over 176,000 persons were listed as killed and almost 50,000 missing in the December 2004 tsunami in the Indian Ocean and South-East Asia, while over 1,000 persons died in severe floods each year over the region.

In the past three decades, the number of geophysical disaster events are more or less constant, while the number of extreme climate and meteorological events have increased markedly over the globe and Asia (Figure 1.14). Asia shared the greatest natural disaster damages of global total in terms of numbers of victims (89%), death toll (57%), economical loss (44%), and number of disasters (37%) (Figure 1.15).

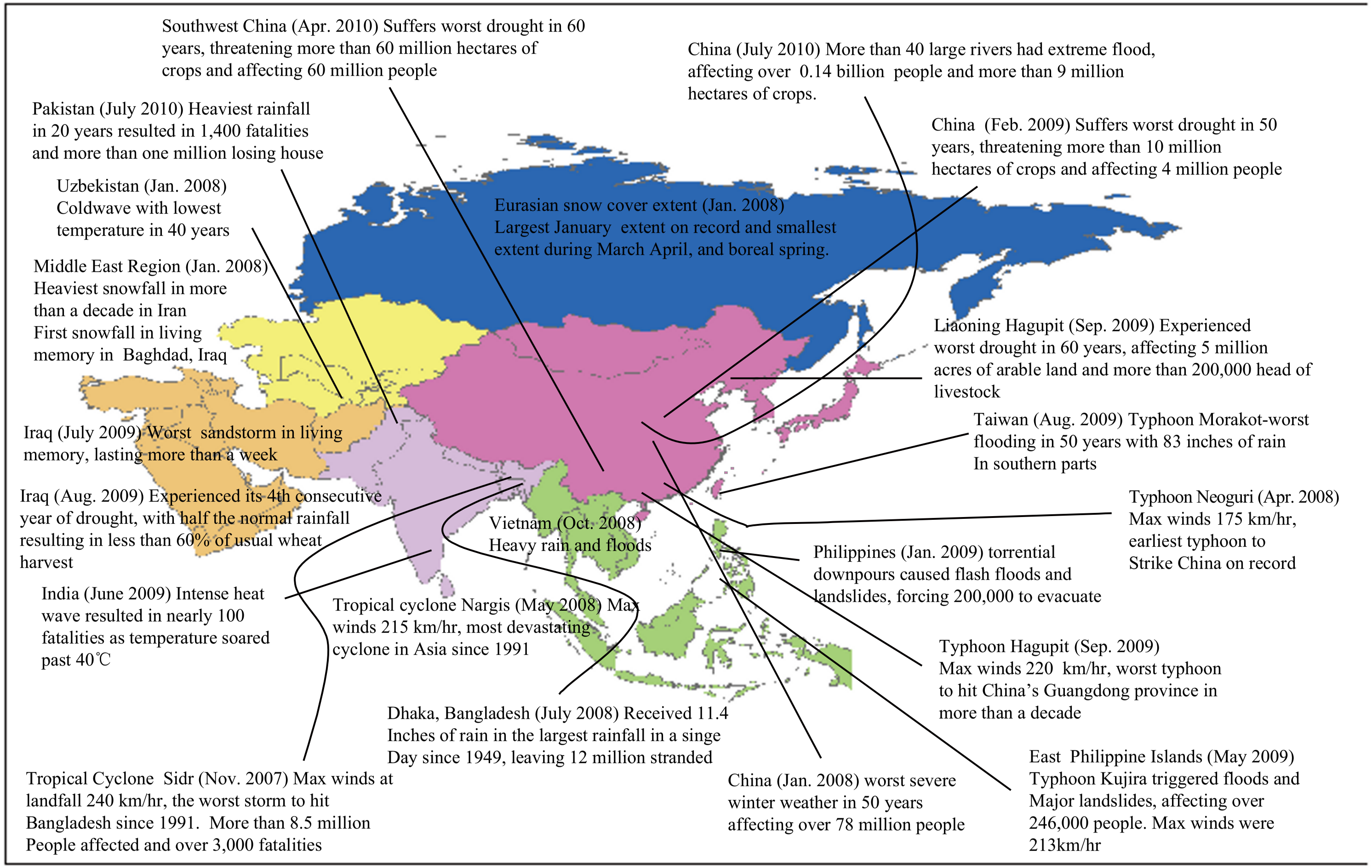


Figure 1.13 The most recent extreme events occurred in Asia (Source: UNEP, 2007, modified)

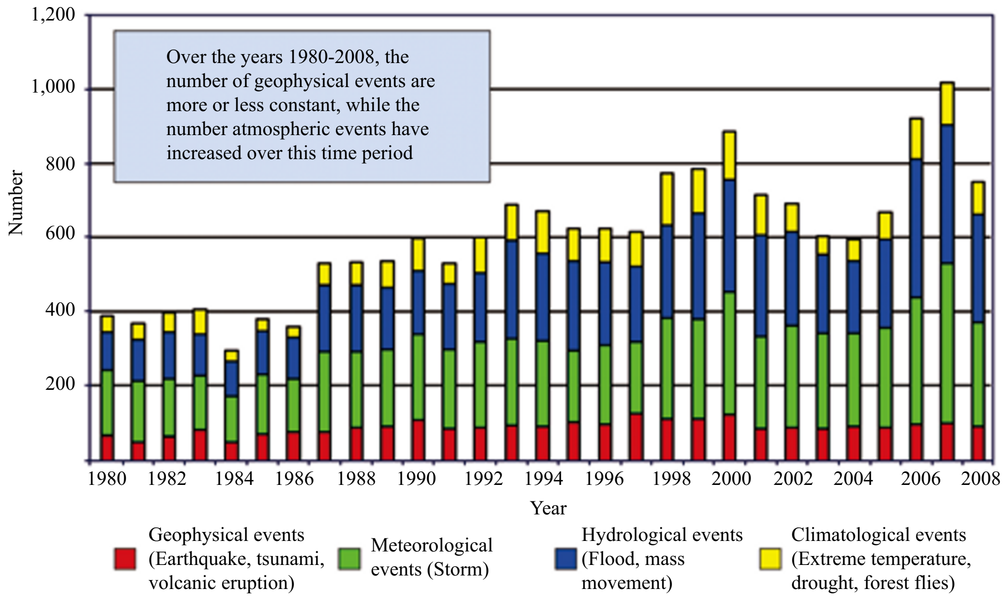


Figure 1.14 Natural catastrophes worldwide 1980-2008 number of events (Source: natural catastrophe review, 2008)

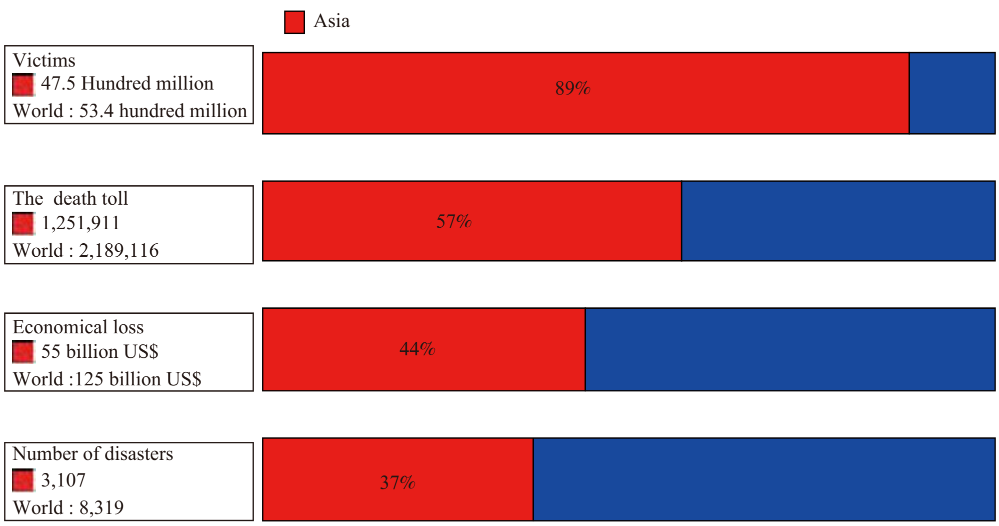


Figure 1.15 Share of global natural disaster damages in Asia,1975-2005 (Source: ADRC-Natural Disasters Data Book 2005)

According to IPCC AR4, All of Asia is very likely to warm during this century; the warming is likely to be well above the global mean in central Asia, the Tibetan Plateau and northern Asia, above the global mean in East and South Asia, and similar to the global mean in Southeast Asia (Solomon et al., 2007). It is very likely that summer heat waves/hot spells in East Asia will be of longer duration, more intense, and more frequent. It is very likely that there will be fewer very cold days in East Asia and South

Asia. Boreal winter precipitation is very likely to increase in northern Asia and the Tibetan Plateau, and likely to increase in eastern Asia and the southern parts of Southeast Asia. Summer precipitation is likely to increase in northern Asia, East and South Asia and most of Southeast Asia, but it is likely to decrease in central Asia. An increase in the frequency of intense precipitation events in parts of South Asia, and in East Asia, is very likely. Extreme rainfall and winds associated with tropical cyclones are likely to increase in East, Southeast and South Asia. Monsoonal flows and the tropical large scale circulation are likely to be weakened.

As monsoons are the dominant phenomena over much of Asia, the factors that influence the monsoonal circulation and precipitation are of central importance for understanding climate change in this region. Precipitation is affected both by the strength of the monsoonal flows and the amount of water vapor transported. Monsoonal flows and the tropical large-scale circulation often weaken in global warming simulations.

Though scientific community still not sure whether or not climate change is the main reason behind increasingly frequent and intensified natural disasters in Asia and the globe, it is clear that extreme climate events have caused the worst loss of human life and properties in recent decades than ever before (Figure 1.13). Deforestation, soil erosion, overgrazing, over-cultivation and other unsustainable agricultural practices and the degradation of natural buffers have seriously reduced resilience of ecosystems and amplified the effects of natural hazards(Table 1.2). Meanwhile, as population continue to grow rapidly in Asia, more people moved to coastal urban areas and marginal lands, made the society more vulnerable to extreme climate events and natural disasters. For example, monsoon frontier in semi-arid region is often seen as promising locations for development of new settlements and cultivation. However, this transitional zone is very vulnerable to fluctuation of rainfall and drought events.

Table 1.2 Impacts and Vulnerabilities of Asia community to Climate Change

Impacts	Sectoral Vulnerabilities
Temperature •Warming above the global mean in central Asia, the Tibetan Plateau, northern, eastern and southern Asia. Warming similar to the global mean in Southeast Asia. •Fewer very cold days in East Asia and South Asia. **Precipitation, snow and ice** •Increase in precipitation in most of Asia. Decrease in precipitation in central Asia in summer. •Increase in the frequency of intense precipitation events in parts of South Asia, and in East Asia.	**Water** •Increasing water stress to over a hundred million people due to decrease of freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins such as Changjiang. •Increase in the number and severity of glacial melt-related floods, slope destabilization followed by decrease in river flows as glaciers disappear. **Agriculture and food security** •Decreases in crop yield for many parts of Asia putting many millions of people at risk from hunger. •Reduced soil moisture and evapotranspiration may increase land degradation and desertification. •Agriculture may expand in productivity in northern areas. **Health**

Continued

Impacts	Sectoral Vulnerabilities
•Increasing reduction in snow and ice in Himalayan and Tibetan Plateau glaciers **Extreme Events** Increasing frequency and intensity of extreme events particularly: •droughts during the summer months and El Niño events; •increase in extreme rainfall and winds associated with tropical cyclones in East Asia, Southeast Asia and South Asia; •intense rainfall events causing landslides and severe floods; •heat waves/hot spells in summer of longer duration, more intense and more frequent, particularly in East Asia.	•Heat stress and changing patterns in the occurrence of disease vectors affecting health. •Increases in endemic morbidity and mortality due to diarrhoeal disease in south and Southeast Asia. •Increase in the abundance and/or toxicity of cholera in south Asia. **Terrestrial Ecosystems** •Increased risk of extinction for many species due to the synergistic effects of climate change and habitat fragmentation. •Northward shift in the extent of boreal forest in north Asia, although likely increase in frequency and extent of forest fires could limit forest expansion. **Coastal Zones** •Tens of millions of people in lowlying coastal areas of south and Southeast Asia affected by sea level rise and an increase in the intensity of tropical cyclones. •Coastal inundation is likely to seriously affect the aquaculture industry and infrastructure particularly in heavily-populated megadeltas •Stability of wetlands, mangroves, and coral reefs increasingly threatened.

Source: Cruz et al., 2007

Increase in current vulnerabilities of Asia society to natural disasters is partly related to the expansion of human settlement into more hazardous areas, such as flood plains, steep and unstable hill slopes, low lying coastal zones, and areas of lower and more uncertain rainfall. Other factors include low quality of construction, and the increase in quantity and value of property and material goods. While the damage in monetary terms from climate variabilities and extremes is also increasing in developed countries, the level of losses appears to be a more or less a constant proportion of gross national product. In other words, losses are increasing in proportion to the increase in wealth. In many developing countries, however, losses are increasing more rapidly than the increase in national wealth. In the case of some recently reported extreme climate events, the losses recorded in a few days are equal in value to a decade or more of economic growth. Even without climate change, current extreme events can be a significant setback to development. This has long been a well recognized phenomenon in drought prone regions, and is now coming to be recognized for other types of climatic hazard as well.

Again, based on IPCC best available climate scenarios, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease by 2050s. Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at the greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development in Asia. The crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events. The retreat of glaciers and permafrost in Asia in recent years is unprecedented as a consequence of warming. The frequency of occurrence of climate-induced diseases and heat stress in Central, East, South and South-East Asia has increased with rising temperatures and rainfall variability. Observed changes in terrestrial and marine ecosystems have become more pronounced.

2 Sensitivity and Vulnerability Across Asia—Ecoregional Perspective

Asia is characterized by diverse geography that includes the largest plateaus, the highest mountain peaks, the longest coastlines, along with vast dryland areas and 7 out of 10 global mega-cities in the world. The continent also has diverse habitats ranging from glaciers to deserts, extensive semi-arid zones to tropical rainforests. Dust storms and soil erosion are almost symbolic for arid and semi-arid areas in Asia, while a long coastline with major deltas and ports includes most of the largest cities and agricultural bases.

The key environmental problems and impacts of climate change are highly differentiated throughout Asia. Parts of society and some ecosystems are much more vulnerable than others. Four locations, dryland, highland, urban, and coastal areas are believed critical or vulnerable to climate change and are experiencing serious environmental deterioration (Figure 2.1). Air quality and health as well as disaster risk are important in each zone but they involve different

Figure 2.1 Four types of ecoregions in Asia: dryland (light pink), highland (see terra), urban (red patches), and coastal areas (blue belts). Note that only part of Asia is shown to represent those types. Image is designed by Hao Gao & Gensuo Jia based on land cover (NASA, 2009) and DEM (USGS, 2000)

phenomenon respectively Therefore, they are highlighted in the report. Ongoing and projected impacts of climate change and key environmental problems over each foci areas are analyzed and mapped (Box 2.1).

Box 2.1 Schematic summary of impacts of climate change and trends of environment on four sensitive ecoregions in Asia

Region wide impacts

- Increased extreme weather events and consequent natural disasters, especially floods, typhoon, drought, heat wave, and wildfire;
- Threatened crop production and aquaculture;
- Increased risk of vector borne diseases, such as malaria and dengue fever;
- Widespread damage of natural ecosystems and loss of biodiversity;
- Continuous deteriorations of environmental quality and land degradation.

Coastal Asia

- Enhanced risk to life and property in coastal low-lying areas of cyclone-prone countries as consequence of sea level rise;
- Exacerbated vulnerability from more frequent and intensified typhoon and floods;
- Saltwater intrusion of freshwater aquifers;
- Coastal erosion and inundation;
- Eutrophication affecting fisheries and biodiversity.

Dryland Asia

- Drier conditions in summer leading to severe droughts and increased sand storms;
- Glacial melt inducing floods in short-term and threatening water supplies in a long run;
- Fall in agricultural yields due to water stress, loss of soil fertility, and wind damage;
- Rangeland degradation and loss of properties of herdsmen.

Highland Asia

- Permafrost degradation;
- Declining duration and extent of snow cover;
- Glacial melt threatening water supplies in highland and downstream areas;
- Lengthening of growing season and possible rise in agricultural yields;
- Invasion of warmth limited pests and diseases.

Urban Asia

- Worsening air pollution, noise, and solid waste accumulation;
- Enhancing urban heat islands and impacts on health and infrastructure;
- Increasing greenhouse gas emissions.

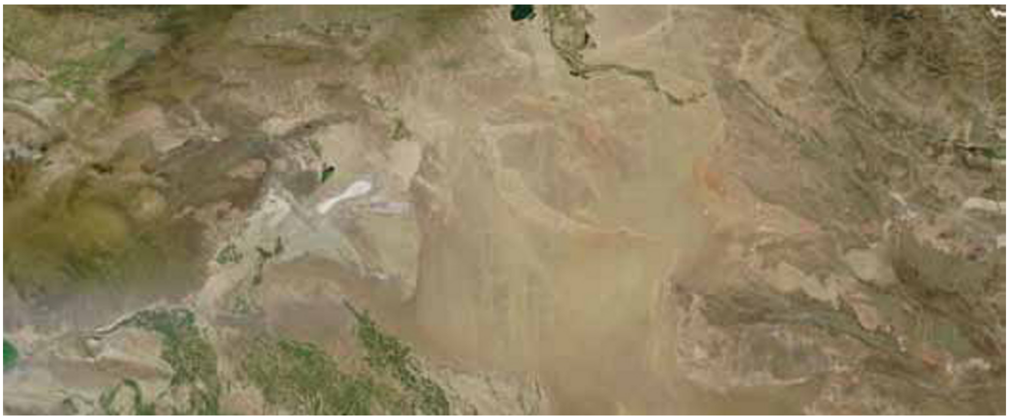
2.1 Dryland (Arid and semi-arid areas)

The vast arid and semi-arid region in Asia was formed in the evolution processes of planet earth in 3.6-2.5 million years ago when the Tibetan Plateau rapidly rose (An et al., 2001). The geographical distribution of arid and semi-arid region in central Asia and south Asia was defined according to humidity index (Figure 2.2). The key climate and environment characteristics in the region are low precipitation, high evapotranspiration, sparse vegetation, poor soil fertility, and vulnerability to extreme climate events such as drought. Asia Drylands are also known as the major source of dust aerosols, which not only directly causes serious damage to human health, agriculture and economics in regions, but also to other regions through long distance transport of huge amount of dust particles across the Pacific Ocean and west coast of North America. The dust aerosols also have significant influence on the regional and global climate through their radiative forcing. Upon deposited in the ocean, aeolian mineral dust is important to many biogeochemical cycles, including the growth of phytoplankton, which will influence the carbon cycle in the ocean. Interactions between dust aerosols and the hydrological cycle were also suggested by many studies.

Asia arid and semi-arid region, expanded from Central Asia, West Asia, western China, to Mongolia, is particularly vulnerable because of its harsh natural environment, its relative underdevelopment resulting from an economic focus on livestock production and rain-feed agricultural. Meteorological data series available since the end of the 19th century show a steady increase of annual and winter temperature in this region. Both aggregated temperature data downloaded from the Climate Research Unit dataset (Jones et al., 1999) and earlier study of individual weather stations across the region (Lioubimtseva et al., 2005) indicate a steady significant warming trend in this region. Meanwhile, arid and semi-arid China suffered from both continuous water deficit and increasing pressure of intensified land use.

Semi-arid area is a transitive zone between arid continent climate and humid monsoon climate, which is very sensitive to the climate and human perturbation. These areas are most vulnerable in global environmental change. There is a trend of aridification in arid and semi-arid Asia, especially in semi-arid areas as global warming continues (Fu, 2003). The rapid economic development in past 2-3 decades in Asia drylands greatly altered land use and land cover, accelerated land degradation, reduced water storage, and increased frequency of sand storms. Such large scale modification of land surface may even weaken summer monsoon and therefore prevent wet air mass from reaching inland region. The positive feedback loop could lead further drought in monsoon Asia region (Fu, 2003).

(a) Desert-steppe ecotone in west China



(b) Satellite view of desert-steppe ecotone

Figure 2.2 Vast arid areas in west China and Mongolia featured with sparse shrubs and graves, as seen in the field (a) and from satellite (b) (Credit: (a) Gensuo Jia; (b) NASA)

Most critical environmental and climate change issues in Asian arid and semi-arid regions are:

(1) increasing variability in precipitation and crop yields;
(2) drought and water shortage;
(3) land degradation and dust storm;
(4) conversion of natural vegetation into cropland;
(5) declining wetlands and oasis.

2.1.1 Food security

Climate aridity is the primary constraint limiting the portion of land available for agriculture and livestock production in Asia drylands. Most croplands in those areas are irrigated and agriculture is potentially highly vulnerable to climate change because of degradation of limited arable land. Almost two-thirds of domestic livestock are supported on grazing lands, although in China and Kazakhstan a significant share of animal fodder also comes from crop residues. Climate change can affect food production in Asia drylands in several ways. Changes in temperature and precipitation regimes are likely to impact agro-ecological potential and constraints, including ① changes in the area suitable for growing rain-fed production of cereals and other food crops; ② changing sustainable stocking rates; ③ modifying crop irrigation requirements.

Main part of agriculture in arid areas deeply relies on irrigation, and irrigated cropland is mainly distributed in lowland, river valleys and oasis. Rain-fed agriculture is widely practiced in semi-arid areas in Asian developing countries. It is often vulnerable to climate variability. There is increasing climate extreme that featured with severe drought in semi-arid Asia region. Most recent severe drought and declining crop yield was in summer 2009 when soil moisture reduced to about 77% of normal level and crop yields dropped to 71% of normal level in some provinces in north and northeast China (Figure 2.3).

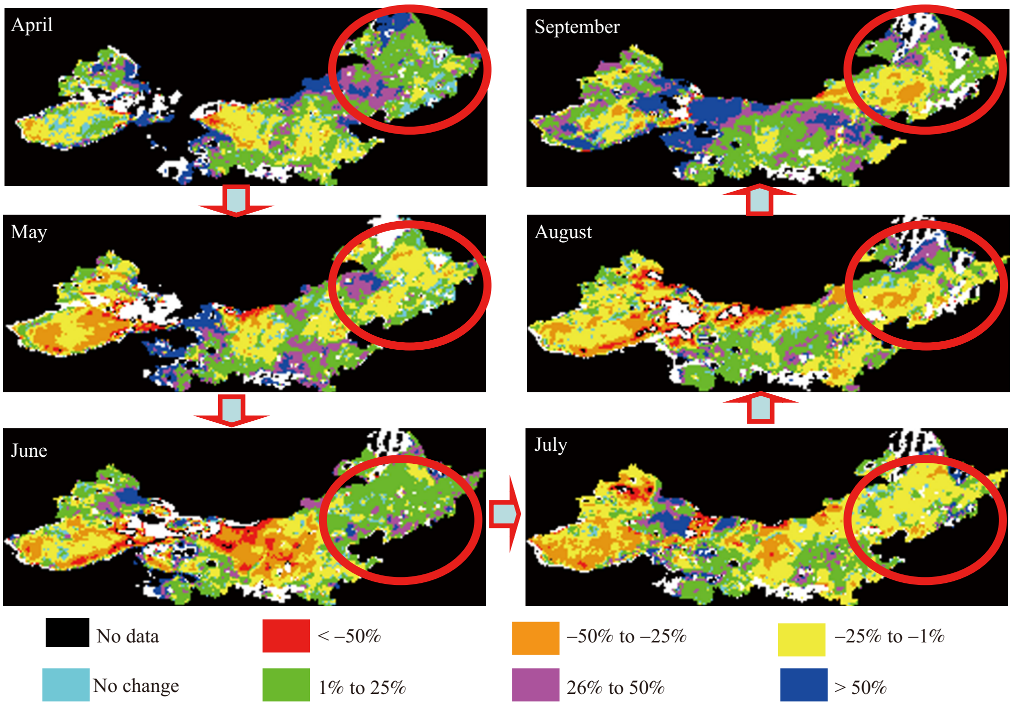


Figure 2.3 Severe drought in north and northeast China in summer 2009 as indicated by comparing soil moisture between 2009 and 2003-2008 average with integrated aqua/AMSR-E and field soil moisture. Analyzed by Anzhi Zhang and Gensuo Jia with NASA data

As agriculture production generally increases in Asia dryland, the efficiency in using irrigating water and fertilizer is still very low. The traditional crop varieties still dominate the croplands, although more drought/pest resistant varieties of corn, wheat, and other crops are already developed for years. Water waste in irrigation is enormous with traditional open surface irrigation and free water use. Water saving technologies such as pipeline irrigation and irrigation on demand work well in several experimental sites, but their application is not well accepted among farmers.

2.1.2 Water stress

Both the observation and numerical modeling have shown that a drying trend is occurring and will occur most significantly in Asia semi-arid regions under the global warming (Ma and Fu, 2005).

Meanwhile, Asia semi-arid region has experienced significant change of land cover driven by intensified human activities in past 2-3 decades. The human-induced land cover changes in this region have brought about further land degradation, the expansion of land under desertification, loss of groundwater reservoirs, and more frequent dust storms. The large-scale destruction of natural vegetation by human activities would also influence the intensity of the summer monsoon and reduce the moisture transfer into the continent, which would enhance the aridity even more over the semi-arid regions (Fu, 2003).

The semi-arid regions are transitive zones between arid continent climate and humid monsoon climate, which are very sensitive to the climate fluctuation and human perturbation. With annual potential evaporation generally excesses the precipitation, the landscapes in those regions are characterized by dry climate, low vegetation cover, low soil nutrition content, and low capacity of water conservation of the soil. These regions are among the most vulnerable ones to global environmental change. Both observation and numerical modeling have shown that a trend of browning (increases in aridity) is occurring and will occur significantly in semi-arid regions as air temperature continuously rises.

On the other hand, as dominated by dryland ecosystems that are vulnerable to climate fluctuation and disturbance, semi-arid regions are also experience significant alterations of land cover driven by human activities and accelerated by climatic change. The human-induced land cover changes in these regions have triggered expansion of desertification, declining of primary productivity, threatening to biodiversity, reduction of soil fertility, loss of groundwater reservoirs, and the increase of dust storm frequency. The large-scale destruction of natural vegetation by human activities could also influence the intensity of the summer monsoon, and therefore weaken the transportation of moist air mass into inland areas, which could enhance the aridity even further over semi-arid regions located at monsoon frontiers.

The low precipitation in combination with the high potential evaporation limits the possible types of land use in arid region. The growing of crops and vegetables is only possible with irrigation. Since, even in this semi-arid to arid region most of the precipitation falls as heavy rain, flood is a serious threat because the parched soil cannot absorb a great quantity of water in a short time. Therefore, most of the rainwater remains on the surface.

Water issues take on special importance in Asia drylands. They are complex and compelling with the rapidly shrinking Aral Sea, transgression of the Caspian Sea, an immense cotton industry, huge deserts, and advancing desertification. The impact of climate change on this highly vulnerable area includes growing demand for water for irrigation, high levels of water pollution, and frequent droughts and widespread land degradation. Overall water withdrawals in the Central Asia States have increased from 37 km^3/

year in 1950 to 102 km^3/year in 2000 and are projected to reach 122 km^3/year by 2025 (Shiklomanov and Rodda, 2001). The core regional problem, however, is not the lack of water resources but rather their management and distribution. In fact, parts of Central Asia have a great amount of water: Kazakhstan, for example, claims more than 85,000 rivers and streams, and 56% of its 100 km^3 annual river flow is formed on the territory of Kazakhstan itself. A lack of coordination among irrigation systems, pervasive soil degradation, and inter-basin transfers are the persistent water problems in the region.

Since 2000, series of droughts have affected Turkmenistan, Uzbekistan, Tajikistan, Iran, Afghanistan, and Pakistan. These droughts have amply demonstrated the very high human vulnerability of this region to precipitation deficits. Agriculture, animal husbandry, water resources, and public health have been particularly stressed across the region as a result of the recent drought (Lioubimtseva and Henebry, 2009).

Asia drylands are among the most vulnerable regions in the world. They suffer from a rainy season lasting just a few months in summer, and a significant shortage of water resources for most of the year. The system is featured by the unreliability of rainfall, and the threat of recurrent drought. Traditional practices to help cope with drought include the accumulation of a surplus in good years, in cash or assets such as cattle, and the use of this surplus in order to survive the bad years. Other strategies include mobility, the use of diverse crop and livestock varieties, the pursuit of off-farm activities, and migration to earn cash during the long dry season. If drought increases in frequency and intensity with climate change, it becomes harder to accumulate a surplus in the good years, and the bad years come more frequently. The first to feel the impact are the poor with the least adaptive capacity, but no social group, and no nation can consider itself immune from the threat of progressive desiccation.

2.1.3 Desertification

Desertification is a land degradation problem featured with deterioration in soil and plant cover in the arid regions of the world. Desertification in the arid regions of Asia is characterized by overgrazing of the rangelands of the Middle East and Central Asia, water erosion of cultivated lands from eastern China to the Mediterranean Sea, and salinization and waterlogging on a large scale in Iraq, Pakistan, China, and Central Asia. Overgrazing, soil erosion, and salt damage to irrigated land are long-standing problems in the Middle East and Central Asia, as is water erosion on the rain-fed cultivated lands of India, Pakistan, and the loessial plateau of China. Waterlogging and salinization are problems centuries old in the lower plain of the Yellow River in China, but are of relatively recent origin in the Indus Basin of Pakistan and India. Declining biological production as a part of ongoing land degradation process is considered a severe environmental problem in Asia grasslands.

Regional climate change and desertification remain inextricably linked because of feedbacks between land degradation and precipitation. Climate change might enhance desertification through alteration of spatial and temporal patterns in temperature, rainfall, solar isolation, and winds. Several climate models suggest that future global warming may reduce soil moisture over large areas of semi-arid grassland in Asia (Manabe and Wetherald, 1986). Therefore, frequent drought and high human pressure are likely to accelerate the degradation of semi-arid rangeland in Asia.

In China, desertification has usually occurred in arid and semi-arid regions, with annual precipitation <450 mm and spring precipitation <90 mm. Key areas include the regions around the Taklimakan, Badain Jaran, and Kumutage Deserts, some parts of the Tengger, Ulan Buh, and Hobq Deserts, and most parts of the Gurbantunggut, Mu Us, Otindag, Horqin, Hulunbuir, and Nenjiang Deserts (Figure 2.4). Extent of desertification from the 1950s to 2005 in China were recently assessed using aerial photos obtained from the mid-1950s, mid-1960s, mid-1970s, and mid-1980s, Landsat TM images obtained in 2000, and field surveys in 2005. Based on this analysis, the area of desertification in 2000 in arid and semi-arid China totaled 385,700 km^2 (Wang et al., 2004; Wang and Zhu, 2003), located at the margins of deserts and in some steppe regions. Meanwhile, it was reported that from the mid-1950s to the mid-1990s, desertification was reversed in most deserts of arid and semiarid China. Compared with the areas of deserts in the mid-1950s, the area of desert with mobile dunes decreased by 422 km^2, and the area in which mobile dunes became anchored increased by 17, 820 km^2 for China as a whole (Zhong and Qu, 2003). In addition, the area of sandy desertification in 1999 had decreased by 33,673 km^2 by 2004 (SFAC, 2005). Those studies suggest that rehabilitation has occurred continuously from the 1990s to the present in arid and semi-arid China.

There are four main causes for the land degradation process. They are:

(1) Harsh natural conditions: Precipitation in the arid and semi-arid region is limited and the ecosystem is fragile. The amount of rainfall varies remarkably between seasons and from year to year; droughts and sandstorms are frequent. Due to the dry ground surface and low vegetation coverage, the sandy soils are very sensitive to wind erosion if vegetation is removed.

(2) Over-utilization of natural resources: Reclamation of marginal land, overgrazing, indiscriminate firewood collection, digging of medical plants, extensive farming, and poorly planned irrigation are causes of desertification in the region. Farmers tend to reclaim sandy grassland for growing crops in years of high rainfall, and then abandon the land in years of low rainfall. This temporary cropland is so-called "try-chance farmland".

(3) Overgrazing: The reasonable grazing supporting capacity is often greatly exceeded for economic reason; overgrazing gets even more serious during dry years when carry capacity of grasslands are much lower than normal years.

(a) Edge of the Tengger Desert

(b) Satellite view

Figure 2.4 Expansion of sandy desert along edge of the Tengger Desert, as seen in the field (a) and from satellite (b) (Credit: (a) Gensuo Jia; (b) Digital Globe)

(4) Improper land restoration practices: many land restoration practices have focused on planting trees in this arid region, and also tried to flatten sand dunes for cultivation. There is also wide confusion between natural sandy land and desertification.

There is still major uncertainty remained in predicting the impacts of broader global climate change on dryland areas. Such predictions are difficult because they depend on the assumptions and models used. In the case of Asia dryland, recent research presents a range of possible rainfall scenarios. Some studies suggest a considerable drop in rainfall, rise in temperature and increased rainfall variability, especially at the start of the rainy season in semi-arid Asia. Meanwhile, others indicate that the many arid areas of northwestern China and Central Asia may actually get higher levels of rainfall.

2.2 Highland areas

Highlands refer to areas of plateaus, alpine, and subalpine mountains that are distinguishable from surrounding plain areas in terms of bioclimate and geomorphology. High elevations have a considerable role and global importance as environmental resources. They are the sources of most major rivers that shape the landscapes in their watersheds, transport nutrients and sediments that drive the global biogeochemical cycles, and provide water for domestic consumption and industrial use including agricultural irrigation. High elevations are home to a large portion of undisturbed natural ecosystems that are rich in biodiversity. Global climate change and human forces have already placed significant impact over high elevations through the melting of glaciers, alteration of land cover and vegetation, loss of biodiversity, and changes of run-off. More importantly, those changes put higher pressure on local communities and confront their traditional ways of life. On the other hand, historical and current changes in high elevations could influence regional even global climate through carbon sequestration and change of energy balance.

Large portion of Asia is high mountains and plateaus, this is especially true in East Asia, Central Asia, and southwest Asia. The highest mountain peak (Mt. Everett) and highest plateau (the Tibetan Plateau) are located in Asia. Countries in the highlands are expected to experience a greater change in climate than those in plains due to their greater sensitivity to fluctuation of air temperature.

Most critical environmental and climate change issues in Asian mountains and plateau regions are:

(1) Deforestation, soil erosion, and loss of biodiversity;
(2) Much more vulnerable to warming than lowland areas;
(3) Melting glaciers and thawing permafrost;
(4) Disturbances to watershed hydrology;
(5) Increasing human pressure and pollutions.

2.2.1 Deforestation, soil erosion, and loss of biodiversity

Asia mountain and plateau region is well-known for its diverse natural habitat and biodiversity along vertical zonation that supplies the inhabitants with essential ecosystem goods and services. Mountains and plateaus appear to be highly vulnerable to the combination of global environmental changes and more locally wrought transformations of land and water use.

According to the third edition of the Global Biodiversity Outlook, the world did not achieve the goal to slow down the speed of biodiversity decrease.

The main reason leading to the failure of global biodiversity conservation is that people did not pay enough attention to the ecological resources, and do not fully aware of the value of these resources. Human survival is dependent on them. At present, the forest resources facing two big threats: one is that the Asian forests have disappeared faster; another is the forest decreasing in Africa. Due to the pressure of concentration of Asian population and increase of commercial cutting, the remaining forests are gradually disappearing, and loss of forest in some Asian countries would even be disastrous. It also brings the problems of soil erosion, and water resource and biodiversity decrease (Figure 2.5).

(a) Rich plant species diversity on top of the Yanshan Mountain in north China

(b) Erosion due to forest disturbances along the Lanchang River, China

Figure 2.5 Asia mountain ecosystems are vulnerable to soil erosion and loss of biodiversity (Photo credit: (a) Gensuo Jia; (b) Xia Li)

Some Asian developing countries including China and India have made great contributions to protect forest vegetation in recent years. China and India participate actively in the activities of “planting 10 billion trees for the earth” initiated by UNEP. According to the statistics of UNEP, Asian forest area increased nearly 1 million square kilometers per year in the year 2000 to 2005 only as a result by the afforestation program in China. Over past 10 years, the forest area in this region has been realized for net growth.

2.2.2 Melting glaciers and thawing permafrost

Seventy percent of the world’s freshwater is frozen in glaciers. Glacier melt buffers other ecosystems against climate variability. Very often it provides the only source of water for humans and biodiversity during dry seasons. Recent evidence suggests an acceleration of glacier mass loss in several key mountain regions (Dyurgerov and Meier, 2005).

The Global Land Ice Measurements from Space (GLIMS) project supported by NASA and the US Geological Survey (http：//www.glims.org) is using remote sensing imagery and field survey data to map most of the world’s glacierized areas and to assess changes in ice extent (Kieffer, 2000; Bishop et al., 2004). Initial results have been obtained from analysis of images for some regions of Asia. The changes involve: a decrease in average size and volume of glaciers, glacier terminus retreat, the disappearance of former small glaciers, and moraine development on the glacier surface etc.

In Central Asia, glacier degradation is accompanied by increasing debris cover on many glacier termini and the formation of glacier lakes (Ageta et al., 2000). Such lakes, sometimes also dammed due to glacier surges (Kotlyakov et al., 2008), have the potential to threaten downstream areas with outburst floods (Wessels et al., 2002). The mountain ranges of Central Asia function as water towers for millions of people. Glacier runoff thereby is an important freshwater resource in arid regions as well as during the dry seasons in mon-soonal affected regions (Barnett et al., 2005) (Figure 2.6).

The Himalayas have the largest concentration of glaciers outside the polar caps. With glacier coverage of 33,000 km^2, the region is aptly called the “Water Tower of Asia” as it provides around 8.6×10^6 m^3 of water annually (Dyurgerov and Maier, 2005). These Himalayan glaciers feed seven of Asia’s great rivers: the Ganges, Indus, Brahmaputra, Salween, Mekong, Yangtze and Yellow. It ensures a year round water supply to millions of people.

Climate change has impacted the glacial ecosystem tremendously. Sixty-seven percent of glaciers are retreating at a startling rate in the Himalayas and the major causal factor has been identified as climate change (Ageta and Kadota, 1992; Yamada et al., 1996). Glacial melt will affect freshwater flows with dramatic adverse effects on biodiversity, people and livelihoods, with a possible long-term implication on regional food security.

(a) Alpine eco-tourism

(b) snow/glaciers

Figure 2.6 Alpine eco-tourism and snow/glaciers at the Tianshan Mountain near Almaty, Kazakhstan (Photo credit: Gensuo Jia)

Throughout the Greater Himalayas, water melts from permanent snow and ice and from seasonal snow packs and is stored in high-elevation wetlands and lakes. Melting occurs mainly in mid summer, but when this coincides with the monsoon, it may not be as critical for water supply as melting in the spring and autumn. When the monsoon is weak, delayed, or fails to materialize, melted water from snow and ice limits or averts catastrophic drought (Meehl, 1997).

The contribution of snow and glacial melt to the major rivers in the region ranges from less than 5% to more than 45% of average flows (Xu et al., 2007). Melting snow and ice contribute about 70% of summer flow in the main Ganges, Indus, Tarim, and Kabul Rivers during the shoulder seasons (i.e., before and after precipitation from the summer monsoon) (Singh and Bengtsson, 2004; Barnett et al., 2005). The contribution of glacial melt to flows in inner Asian rivers is even greater (Chen et al., 2006). Indus River irrigation systems in Pakistan depend on snowmelt and glacial melt from the eastern Hindu Kush, Karakoram, and western Himalayas for about 50% of total runoff. In western China, about 12% of total discharge is glacial melt runoff, providing water for 25% of the total Chinese population in the dry season (Xu et al., 2008).

2.2.3 Warming and hydrology

Asia mountains and plateaus have a profound effect on the weather and climate of the world, particularly as they include the Himalayan-Tibetan Plateau, which is the largest high-elevation region of the world. With an average elevation of more than 4,000 m, the plateau has a direct effect on global circulation patterns by causing perturbations in the prevailing westerlies. The region is also a major determinant of the Asian monsoon, acting as an elevated heat source in the summer and a source of cold air in the winter.

One of the most important services from mountain ecosystems is the provision of freshwater. Hydrology is therefore a crucial node in mountain ecosystems. It is directly affected by changes in climate, by influencing land use and land cover change and by variations in the cryosphere. These impacts in turn influence the quality and quantity of freshwater supplied to the adjacent areas, as well as other goods and services such as slope stability, biodiversity and energy production.

The dramatic retreat of high-mountain glaciers as a result of global warming has led to increasing flow at the beginning of the snow-melt period followed by flow reductions as the snow mass decreases or disappears later in the season. In many mountain regions and mountain fore-lands this process will result in a reduction in annual river flow in the long term. Thus mountain regions are now the hotspots of impacts of global change; they are associated with the rapid retreat of glaciers, producing climate change and variability with more extreme climatic events.

Theoretically, high elevation areas are sensitive to climate warming as warmth limited landscapes. Progressive increases in warming at high elevations are already occurring at approximately 3 times the global average (IPCC, 2007; Nogues-Bravo et al., 2007). In the Greater Himalayas processes determining the conversion of glaciers, ice, and snow into runoff and downstream flow are complex, but the impact of climate change on river regimes will very likely be profound. Initially, increased melting will result in increased discharge. With time, however, as glaciers completely disappear or approach new equilibria, long-term effects will be increasing water shortages and limited supplies for downstream communities, particularly during the dry season. Based on current knowledge, the rivers most likely to experience the greatest loss in water availability due to melting glaciers are the Indus, Tarim, Yangtze, Brahmaputra, and Amu Darya (Table 2.1). Changes have already been observed, but there is still uncertainty regarding when tipping points will be reached.

Table 2.1 Predicted hydrological responses of 10 rivers in the Greater Himalayan region to climate change

River (basin area) /km^2	Glacial melt in river flow /%	Signal of trends	Probable future
Tarim (1,152,448)	40.2	wetter in past half century; increasing river flow in some tributaries; 9 tributaries dried up	sharp drop in run-off in glacier retreated catchment, floods occur owing to extreme rainfall
Amu Darya (534,739)	10-20	increase in precipitation but drop in annual runoff	by 2100, probability of river runoff increase of 83%-87% owing to mainly an increase in precipitation
Indus (1,081,718)	44.8	significant increase in rainfall (19%); increase in river flow between 14% and 90%	flow from glacial sub-basin peaks at about 150% of initial flow around 2060; 4% less annual mean flow
Ganges (1,016,124)	9.1	slight increase in rainfall and heavy rain; decrease in rainy days per 100 years	flow from glacial sub-basin peaks at about 170% of initial flow around 2070; 18% less annual mean flow
Brahmaputra (651,335)	12.3	increase in runoff (low flow and high flow); nosignificant change in precipitation but change in runoff at lower basin	annual flow in Lhasa River increases by 11.3% and monthly maximum flow increases by 45% in 2050s
Irrawaddy (413,710)	Small	unknown	unknown
Salween (217,914)	8.8	increase in river flow during monsoon	river-flow decrease over short term (2010-2039) and increase over long term (2070-2099)
Mekong (805,604)	6.6	increase in precipitation during early monsoon; increase in runoff	rainfall and extreme floods increase

Continued

River (basin area) /km^2	Glacial melt in river flow /%	Signal of trends	Probable future
Yangtze (1,722,193)	18.5	increase in precipitation, extreme rainfall and frequent floods; no significant change in runoff	glacier areas in upper Yangtze decrease by 11.6% and glacial discharge runoff increases 28.5% by 2050
Yellow (944,970)	1.3	no significant change in precipitation, but significant decrease in runoff	rainfall and evapotranspiration increase: river flow decreases
	17.4 (average)		

Source:
Xu et al., 2009

The relatively harsh conditions of mountains have tended to limit the population of this zone, and the population density has been rather low. However, in recent decades, there has been a trend towards both depopulation and urbanization, leading to the development of dense urban areas. Mountains often have great spiritual, cultural and historical value for people.

There are increasing urbanization processes and air pollution in many mountainous areas in Asia, especially in South Asia. The increases in human activities in mountain areas will certainly post additional pressure on the environment and ecosystems in the region.

2.3 Coastal areas

Over 60% of population and 2/3 of major cities are located along the coastal areas in the world. Asia has the longest and the most complex coastlines, and many Asia countries are islands. Special features such as daily tides, storm waves, tidal flats, mangrove forests, coral reefs, and vast sandy beaches exist only on the coast. On the other hand, coastal zones are used for human settlement, agriculture, trade, industry, and amenity and as shore bases for maritime activities such as shipping, fishing, aquaculture, and sea mining. In the same coastal zones, destructive natural disasters take place, killing ten of thousands of people and destroying upland properties, as demonstrated by the tsunami disasters. Asia coastal zones are threatened by the combined effects of population growth, urban and agricultural development, industrial expansion, recreational pressures, offshore waste disposal, the exploitation of freshwater and marine resources, coastal erosion, overextraction of groundwater and the impacts of rising sea levels.

Most critical environmental and climate change issues in Asian coastal and islands regions are:

(1) Inland source sediments and water pollutions;

(2) Eutrophication and harmful algae bloom;

(3) Sea level rise, coastal erosion, and saltwater intrusion;

(4) Extreme precipitation events and natural disasters;

(5) Damage of mangrove and coral reef and declining fish stock.

A large percentage of Asia's population lives in coastal areas and on the many low-lying offshore islands. Most of these people depend on coastal and marine resources for their livelihoods. Coastal aquaculture has been the most important fishery activity in Southeast Asia with more than 30,000 households, in more than 64,000 ha, earning their livelihood from shrimp farming. In recent decades, however, all coastal areas and marine resources in Southeast Asia have been affected by global warming, extreme events, and rising sea levels.

Typhoons, storm surges and tsunamis have maximum impact on coastal zones, often resulting in huge losses of human life in the Asia coastal region. Evidence indicates that sea levels are rising and major typhoons are stronger and occurring more frequently because of warmer seawater (Emanuel, 2005). Meanwhile, humans have overexploited groundwater, which has resulted in land subsidence and seawater intrusion. Humans have also removed large swathes of mangroves and have reclaimed land from wetlands and coral reefs, resulting in a loss of natural buffers against sea-borne disasters.

Asia is undergoing unprecedented urban growth that will add substantially to the population residing in its coastal regions (Figure 2.7). Much of this rapid population and economic growth is occurring in large coastal cities at high risk from sea level rise and climate change. Asia's densely populated deltas and other low lying coastal urban areas are among those key societal hotspots of coastal vulnerability with many millions of people potentially affected. The potential for loss in the region has been amply demonstrated in the recent past by loss of life and property from flooding, particularly when high tides were combined with storm surges and high river flows. The risks posed by climate change to Asia's coastal population will persist, despite any greenhouse gas stabilization, in the future sea level rise and climate change are unavoidable given existing high atmospheric CO_2 levels and projected growth in population and infrastructure.

Important atmospheric and oceanic phenomena that occur in the Asia coastal region, such as the Asian monsoon and the ENSO, are highly variable. Within the region, the occurrence and variability of these phenomena induce a tendency for increased extreme climatic events, such as frequent droughts and heavy rains.

Economic activities of many of the Asian countries heavily depend on developments of the coastal zones. In line with global trends, more than half of the region's population presently resides in the coastal zones. The consequences of this population growth, accompanied by rapid urban expansion and industrial development, pose a significant threat to the vulnerability of the

Asian coastal zones. All coastal areas are facing an increasing range of stress and shock caused by natural disasters like tsunami and storm surges.

(a) The Halong Bay, Vietnam

(b) Istanbul, Turkey

Figure 2.7 Coastal land use and development in Asia (Photo credit: (a) Xia Li; (b) Gensuo Jia)

2.3.1 Coral bleaching

Coral bleaching has significantly increased in recent years due to global warming. Coral bleaching is a stress response in which the coral animal expels most or all of its endosymbiotic zooxanthellae (Brown, 1997). In the extreme case, the bleaching response is fatal to the coral host, and can devastate entire reefscapes over vast areas of ocean (e.g., McClanahan, 2000; Sheppard, 2003).

A diverse range of stress factors (e.g. low salinity, low temperature, high sedimentation, aerial exposure, cyanide exposure) can initiate the bleaching response, although the combination of high irradiance and anomalously warm sea surface temperatures (SSTs) is the primary triggering condition for the modern occurrence of large-scale mass bleaching events (Hoegh-Guldberg, 1999). Indeed, coral bleaching has consistently occurred where normal summer sea temperatures have exceeded ambient by 1–2°C for more than a few days (Hoegh-Guldberg, 1999). In addition to these factors, it has recently been demonstrated that corals which regularly experience poor water quality conditions.

Coral bleaching is the most commonly reported impact of climate change on marine resources. Coral bleaching has increased significantly since 1979 in Asia. The most significant mass bleaching event on record was associated with the 1997–1998 El Niño, when vast and diverse coral reefs in Southeast Asia were reported to have been lost (Wilkinson, 2002; Arceo et al., 2001). According to Wetland International, the 1997–1998 El Niño damaged about 18% of the coral ecosystems in region (Burke et al., 2002).

Coral bleaching was observed in many parts of Indonesia, such as in the eastern part of Sumatra, and in Java, Bali, and Lombok. In Thousand Islands, about 90%–95% of corals 25 meters below the surface were bleached. In the Philippines, the recent sea surface temperature increase of 0.5°C above the normal summer maximum temperature, coupled with the associated El Niño periods, started coral bleaching in many areas of the country. Amadore (2005) and Arceo et al. (2001) have reported massive coral bleaching in various reefs caused by elevated sea temperatures also during the severe 1997–1998 ENSO episode.

2.3.2 Mangrove forests degradation

The coastal ecosystems in Asia are diverse, ranging through tropical, subtropical and temperate coastal ecosystems, such as mangroves, coral reefs, sea-grass beds, brackish and marine wetlands and marshlands. These ecosystems are rich in biodiversity and some ecosystems are habitats for rare and endangered species. These ecosystems also provide goods and services for human society, security and economies within and outside the coastal zone. Coastal biodiversity in many Asia countries is an important source of food, energy and income for subsistence livelihoods. In addition there is potential for tourism, commercial and pharmaceutical uses

Mangrove forests occur along tropical and subtropical coastlines and serve as breeding, spawning, hatching, and nursery grounds for many marine species (Baran, 1999; Barbier, 2000). Next to this habitat function, mangroves also provide wood and non-wood forest products and values to indigenous people. They may act as a physical barrier to protect human settlements from the ocean (Badola and Hussain, 2005).

The Indian Ocean tsunami on 26 December 2004 caused catastrophic destruction to coastal communities (Figure 2.8). It resulted in casualties estimated at more than 220,000. According to some reports, however, areas with coastal trees, such as mangroves (which are widespread in Southeast Asia), suffered substantially less damage than areas without them (Danielsen et al., 2005; Kathiresan and Rajendran, 2005). Findings from previous studies have also indicated that coastal trees help reduce the damaging effects of natural disasters. For example, Mazda et al. (1997) observed that sea wave height during a typhoon was reduced by 20% in a mangrove forest with a width of 100 m, and Wolanski (2007) also suggested that coastal trees are useful for the protection of human life and property from natural disasters such as typhoons, as well as coastal erosion, salt spray, and wind damage.

(a) Before the tsunami

(b) After the tsunami

Figure 2.8 Pair of satellite images of the Banda Aceh shoreline in Indonesia before and after the 2004 tsunami (Source: Digital Globe)

Learned from highly differential impacts of 2004 tsunami due to protection of mangrove forests, India and Bangladesh Bengal gradually realized the importance of mangroves in Sunderbans of the Bay of Bengal. It is not only the source of income of the fishermen but also the effective mechanism of coastal protection. Vietnam also invests in recovering of mangrove, as a cost effective mean of protecting coastal area. In Vietnam, tropical storm caused mass loss of living resources, especially in the coastal communities. Along the coast, recovery of mangrove ecosystem in Vietnam is a cost-effective way to improve the coastal barrier, as well as brings means of livelihood to the local (Figure 2.9). Since 1994, the National Red Cross in Vietnam has cooperated with local community in planting and protecting mangrove in northern Vietnam, growing almost 120 square kilometers mangrove and bringing remarkable benefit. Although the cost of planting and protecting mangrove was nearly 110 million dollars annually, but 730 million dollar maintenance costs of seawall was saved. In 2000, during the period of the powerful typhoon "Wukong", the implementation area of mangrove ecosystem restoration in Vietnam was not damaged, but nearby province suffered huge losses of life and property and livelihood. Vietnam Red Cross estimated 7,750 families benefit from the mangrove restoration project (UNEP, 2007). These family members can sell crab, shrimp and mollusks earning additional income as well as increase protein in their diet.

Figure 2.9 Rapid declining of mangrove forest along the coasts near China-Vietnam boarder, largely driven by land use modification (Photo credit: Xia Li)

It has been estimated that approximately 75% of tropical coasts worldwide were once fringed with mangroves. Historically, large tracts of the coastal zone of SE Asia have been occupied by mangroves. During the past decades, these mangroves have been cleared over vast areas to accommodate increasingly intensive forms of land-use for human benefit such as settlement, transport infrastructure, agriculture and aquaculture, especially shrimp farming (Farnsworth and Ellison, 1997).

Climate change components that affect mangroves include changes in sea-level, high water events, storminess, precipitation, temperature, atmospheric

CO_2 concentration, ocean circulation patterns, health of functionally linked neighboring ecosystems, as well as human responses to climate change. Of all the outcomes from changes in the atmosphere's composition and alterations to land surfaces, relative sea-level rise may be the greatest threat (Lovelock and Ellison, 2007). Although, so far, it has likely been a smaller threat than anthropogenic activities such as conversion for aquaculture and filling (Alongi, 2002; Duke et al., 2007), relative sea-level rise is a substantial cause of recent and predicted future reductions in the area and health of mangroves and other tidal wetlands (McLeod and Salm, 2006; Gilman et al., 2007).

In the past 30 years, coastal resources such as mangroves, coral reefs have been depleted on a large scale and this has become a critical issue for the region. For example, more than 60% of Asia's mangroves has been converted to aquaculture farms while the combined effects of higher temperature and pollution of seawater threaten coral reefs; de facto more than 80% to 90% of coral reefs in some countries may already be threatened. Asia and the region are losing resource bases to support people's everyday lives and future economic development as well as rich biodiversity in the coastal zones. If such human-induced pressures are heightened and superimposed by global climate changes, the effects will be devastating for the sustainability of the coastal environment.

2.3.3 Coastal flooding and erosion

Asian coasts are characterized by large and rapid changes in coastal geomorphology in many ways including erosion and the construction of large-scale engineering works. They host large deltas, many of which have suffered from coastal erosion over past decades this opposes the natural deltaic function. Coastal flooding and erosion in Asia have intensified in recent years due to the combined effect of extreme climatic and nonclimatic events. The recent erosion is caused by decrease of sediment supplied by rivers, which is in turn due to river watershed development such as dam construction. For example, the Yellow River in China, which was once the second largest river in the world in terms of sediment discharge, delivers less than 10% of its past discharge because of dam construction and irrigation. This reduction has caused serious coastal erosion around the river's mouth in the East China Sea.

Mangrove forests play a critical role in the protection of coastlines in Southeast Asia. Many of the mangrove forests have been converted into aquaculture and other related projects, and in some cases are converted into human settlements where gathering of mangrove trees for charcoal making and construction materials are practiced unsustainably. As a consequence, many areas have been exposed to tidal waves and coastal erosion.

Coastal flooding and erosion have been accelerated by the destabilization of coastlines due to advancing sea levels and extreme events (such as La Niña and tropical cyclones), causing significant damage in many parts of the region. The tropical cyclones that hit Southeast Asia in recent years, together with storm surges, have accelerated the erosion of beaches, steep bluffs, deltas, and mangrove swamps. This has led to substantial economic losses, loss of lands, and even premature deaths of inhabitants.

Thailand's 2,667-km shoreline is under serious threat from coastal erosion, which is occurring at the rate of 15–25 meters per year in some places. Coastal erosion is a significant problem along the Gulf of Thailand from Trat province in the east to Narathiwat province in the south. Due to coastal erosion and an advancing sea, most of these areas are now deforested, degraded, and devastated, and groundwater resources are already contaminated with seawater. Many families have been forced to abandon their coastal homes, as few people can afford to continue rebuilding houses washed away regularly by the sea. Also in Thailand, storm surges have become stronger and more frequent. Certain spots along the inner gulf (for example, areas along the upper south around Prachuab Khiri Khan, Changwat in southern Thailand) and the eastern tip of the south (in Narathiwas and Songkhla provinces) have been eroded by strong winds and the changing direction of seawater flows (ADB, 2009).

Coastal erosion has been observed in key cities and areas in the Philippines including Cebu and La Union. The factors that may have caused coastal erosion in La Union are relative sea level rise, decrease in precipitation, increase in storm, watershed erosion, beach sand mining, and destruction of coral reefs, mangroves and sand dunes (Siringan et al. 2004).

2.3.4 Rising sea levels

Rising sea levels has caused saltwater intrusion into coastal freshwater and groundwater resources in many areas of Southeast and South Asia. Rising sea levels have also accelerated inundation and land subsidence in coastal cities and communities, resulting in considerable losses to tourism and aquaculture industries. In Indonesia, groundwater resources in a number of metropolitan areas near the coast of Jakarta, Surabaya, and Semarang have been affected by saltwater intrusion. This problem has existed in Jakarta since the 1960s. Saltwater intrusion in the shallow and deep aquifers f Jakarta has reached inland up to 10–15 km from the coastline. The problem has been exacerbated by overexploitation of groundwater, which has caused land subsidence (ADB, 2009).

Rising sea levels is predicted to severely affect millions of Asian. Millions of people living in the low-lying areas of China, Bangladesh, India, Vietnam, and other Asia coastal areas will be affected by rising sea levels by the end of this century. By 2100, under the most common predictions, global mean sea level is projected to increase by 40 cm, which could mean an increase in the average annual number of people flooded within coastal regions, or from 13 million to 94 million people worldwide. About 20% of them will live in Southeast Asia, particularly Indonesia, Philippines, Thailand, and Vietnam.

In Indonesia, rising sea levels, in combination with land subsidence due to overexploitation of ground water, will definitely move the coastline inland, with an associated higher risk of flooding. Dasanto and Istanto (2007) found that when the mean sea level increases by about 0.5 meters and land subsidence continues, parts of six sub-districts of North Jakarta and Bekasi will be permanently inundated. With a sea level rise of about 1 meter, it was estimated that about 405,000 ha of coastal land including small islands will be inundated. The impact may be severe in certain coastal areas such as the north coast of Java, the east coast of Sumatra, and the south coast of Sulawesi (Subandono, 2002).

These risks will be further intensified if sea surges associated with intense storm activities increase. More intense typhoon activities will also pose threats to inland areas where frequent mudslides are triggered by torrential rains associated with typhoons.

2.4 Urban areas

Urbanization doubtlessly has been the most significant demographic trend in the world for at least a century and promises to become even more significant in the future. Nowadays over 50% of the world's population lived in urban areas, and the United Nations estimates that 60% of the population will live in urban areas by 2030. Today, China has approximately the same urban population share as did the United States 100 years ago (45%), and will reach 60% by 2030. Currently about 30% of India's population lives in urban, but the number will increase to 40% by 2030. Now, 13 of the 20 largest urban areas in the world are in Asia. Meanwhile, all five of the largest urban areas in the world are in Asia, they are Tōkyō, Jakarta, Mumbai, Delhi, and Manila. Asia is now no doubt the center of urbanization.

Most critical environmental and climate change issues in Asia urban areas are:

(1) Air pollutions and greenhouse gas emissions from transportation, manufacturing, and household source;

(2) Solid wastes from packaging, industrial processes, and household source;

(3) Water pollution and shortage over both surface and subsurface;

(4) Urban heat islands and heat waves;

(5) Urban flood.

The population of Asia has increased rapidly over the last three decades. In 1995, there were five megacities in Asia. Nowadays, half of the world's megacities are in Asia, population centers with more than 10 million people living in them. Tōkyō and saka became megacities in the 1960s, Seoul, Shanghai, and Mumbai in the 1980s, Beijing and Karāchi in the 1990s, and Jakarta and Manila in the early 2000s. The populations of several other Asian cities are also approaching 10 million, e.g., Dacca, Kolkata, Deli, Tianjin, and Bangkok.

A key point of concern is that the current urban transition is occurring much faster than ever before. What took two centuries in the past will now occur in decades. In addition, the absolute numbers today are much larger than ever. The North Atlantic urban transition involved a few hundred million people; the transition today, especially in Asia, involves billions of people. The greater speed and numbers of this transition impose on Asian urbanization a much greater sense of urgency to identify and address the problems the transition is bringing.

Urbanization is a major driver, and outcome, of economic and social development; this is especially true for the rapid growth of Asia economy in past two decades (Figure 2.10). The life styles of people live in urban areas are crucial to patterns of energy demand for mobility, comfort and the production of consumer goods. In rapidly urbanizing regions in Asia developing countries, deteriorating air quality is a common phenomenon with serious consequences for public health and the environment. Apart from local pollutants, aerosols, trace gases and greenhouse gas emissions may have important impacts regionally and globally. Emissions of aerosols can change the atmospheric heat balance, the size and weight of cloud particles. What influence these have on the intensity of monsoon circulation, onset timing, number of rainy days and extreme events is still not well understood. Increasing urban air pollutants not only post direct harm to local population, but also act as greenhouse gases that enhance global warming.

Figure 2.10 Dense human population and intense urbanization in East Asia, South Asia, and Southeast Asia as detected from satellite. White-yellow areas represent urban areas, while concentrated bright patches are major cities (Source: NASA/US Defense Meteorological Satellite Program (DMSP), 2006)

Urbanization is often accused to cause environmental problems; however, it is likely a not-so-bad solution for increasing environmental pressure in many parts of Asia. Urban provides efficient infrastructure for living and employment of ever increasing Asia population, and therefore, largely released pressure on rural land and natural ecosystems. Urban also offers better management options for energy and water use. And more importantly, urban manufacturing and services are the major contributors for the 20-year Asia economy miracle.

Urban sources of air pollution in Asia have major contribution to low air quality in surrounding areas, and to some extents, to climate change at regional, even global scales. The economic impact of pollution in urban areas in terms of loss of productivity and health costs are estimated to exceed 10 percent of gross domestic product in some countries. Most air pollutants, including CO, NO, SO_2, O_3, etc. are either greenhouse gases or important for climate radiation forcing. Aerosol composition and acid precipitation change seasonally, following seasonal patterns of Asia monsoon.

The urban environment is where an increasing share of the world's population resides, where most commercial energy is consumed, and where the impacts of pollution are felt the most. Rapid economic growth in urban Asia has attracted millions of rural residents to metropolitan environments. Asia presently has approximately 1 billion (26% of total population) urban dwellers, projected to grow at an average of 4% per year to 3 billion (55% of total population) by 2025 (WDI, 2009). These cities are distributed throughout Asia, including Mumbai, New Delhi, Calcutta, Dhākā, and Karāchi in the Indian Subcontinent; Singapore, Kuala Lumpur, Jakarta, and Bangkok in the Southeast Asia; and Beijing, Shanghai, Chongqing, Guangzhou, Tōkyō, Seoul and Pusan in East Asia. Changing standards of living in the urban centers have fueled increasing energy demand often associated with unchecked emissions from automobiles, domestic heating, and small-scale industries. Coal being the cheapest and most widely accessible, is still the primary source of energy in Asia and contributes significantly to sulfur and particulate pollution levels that often exceed the WHO air quality guidelines.

2.4.1 Urban air pollution

Presently, the urban air pollution problems in Asia are continuing to increase and air pollutants originating from urban regions are recognized as increasing sources of regional- and global-scale pollution (Streets et al., 1999). Besides stationary combustion sources such as thermal power plants and industrial estates, air pollution from mobile sources has also become a major contributor to increasing human health effects in the urban environments of Asia (Krupnick and Harrington, 2000). The megacities and major urban areas in Asia cover 0.2% of the land cover but produce 10%–20% of regional trace gas emissions.

In the last two decades, Asian cities have experienced an increased demand for fossil fuels that led to intensified sulfur pollution due to the high sulfur content in locally available energy resources. However, increased pollution awareness campaigns, stringent pollution control regulations, use of low sulfur fuel, implementation of desulfurization techniques, and periodic monitoring have resulted in a significant reduction in sulfur and other trace gas emissions in many cities. Nevertheless, sulfur pollution levels remain significantly above compliance levels throughout large parts of Asia (Klimont et al., 2001; Reddy and Venkataraman, 2002). Environmental and economic costs of human health associated with air pollution arising from energy use are one example of the cost implications of infrastructure choices and urban development.

Asian cities face a serious air pollution problem from two- and three-wheelers vehicles that run on two-stroke engines. Because two-stroke engines burn an oil–gasoline mixture, they emit more smoke, carbon monoxide, hydrocarbons, and particulate matter than the gas-only four-stroke engines found in newer motorcycles. Measurements of how much pollution two-wheelers emit are rare, but one study of traffic intersections in Bangkok, Thailand, found that two-wheelers contributed up to 47% of particulates. When two-stroke baby taxis were phased out of Dhākā, Bangladesh, in 2002, particulate concentrations dropped up to 40%, and carbon monoxide and hydrocarbons fell significantly (Potera, 2004).

Meanwhile, increasing private cars on the streets and worsening traffic jams in most Asia cities post major pressure on urban infrastructure and management, and make it difficult to solve the problems of air pollution. Bicycles and public transpiration have been primary or even only mobility tools in most Asian developing countries over past century, but now they are quickly replaced by automobiles in many Asian cities. Going back is not a solution, but a reasonable balance between them will definitely benefit to both economy and the environment.

RAINS-Asia (Regional Air pollution INtegration and Simulation-Asia) project has estimated emissions of SO_2 from Asia during the period 1975–2000. The project presents the population for year 2000 and total sulfur emissions from a $1^\circ \times 1^\circ$ grid cell covering the city limits of 25 megacities included in this study. Today these urban centers account for an average of 16% of the total anthropogenic sulfur emissions in Asia. For 1990, grid cells containing Karāchi, Mumbai, Bangkok, Singapore, Manila, Hong Kong, Beijing, Shanghai, Chongqing, Guangzhou, Wuhan, Taibei, Seoul and Tōkyō each had emissions in excess of 100 kt SO_2 per year. Chinese cities have the highest sulfur emissions, but SO_2 emissions in many cities have declined in the 1990s. Efforts of national and municipal governments, with the cooperation of private industry, have lead to sulfur pollution control programs in East Asia which have resulted in: improvements in combustion processes; the substitution of coal based applications with low-sulfur fuel and natural gas; a change in fuel standards in the transportation sector leading to a reduction in the S-content of fuels used; and the installation of air pollution control facilities (Shah et al., 2000).

2.4.2 Urban heat island (UHI)

Urban development often causes great modification of land surface properties, landscape pattern, and even local climate through changing land use and cover. Urban expansion resulted by economic development and population growth has changed land surface properties in urban and surrounding areas, including green vegetation cover, surface albedo, surface roughness, and emissivity in many parts of the world, especially in East Asia. Meanwhile, urbanization also alters landscape mosaic in urban or suburban areas. These changes include expansion of tall buildings, roads, and other paved areas into urban-wildland interface, loss of cropland and woodland, and in many cases increase of urban greens such as city parks.

The expansion of so-called urban heat island (UHI) is considered as a direct climate consequence of urbanization, as solar radiation is sequestered by urban architecture. UHI has major impact on urban energy consumption and human health, and therefore needs to be considered in urban planning. Meanwhile, UHI effects could be buffered by green vegetation through solar energy and water flux. Green vegetation cover is also a critical land surface parameter that influences hydrological cycle and exchange of water and energy between land and atmosphere.

Urbanization processes drive environmental change at multiple scales by altering land use and land cover, influencing hydrological systems, and modifying biogeochemical cycles and climate. Economic development also attracts food, fiber, water, and industrial materials to flow into urban area from surrounding countryside. The processes quickly turn surrounding areas into suburban by eliminating nature properties step by step. Dramatic urbanization in Asia's mega-cities is a very common phenomenon that converted large patches of croplands and woodlands into build-up within a matter of decade or even multiple years. Large scale changes of urban landuse patterns in East and Southeast Asia mega-cities have so far resulted in rapid change of land surface properties.

Expansion of urban heat islands has been accelerated in Asian cities. Because of rapid urbanization, urban warming has become a serious problem along with global warming (Nakagawa, 1996; Rizwan et al., 2008). Heat island intensity (HII), difference between urban and rural temperature, is a popular index used for indicating the urban warming trend. Figure 2.11 shows the variation in the E-HII (estimated HII) of the target Asian cities. saka shows the largest E-HII, increasing from approximately 2.4°C in 1901 to almost 3°C after 1981. The E-HIIs of Seoul, Tōkyō, and Taibei, have increased by 1 to 2°C. Jakarta and Bangkok exhibited a lower E-HII. E-HIIs of Manila and Bangkok have been increasing rapidly after 1961 (Kotaoka, 2009). Study also shows the relationship between the E-HII and the population of each of the target cities from 1950 to 2000. There are positive relationships between the E-HII and the population in each city. In eastern China, remotely sensed thermal infrared data have demonstrated the land surface temperature can get 2.5°C higher in city center than nearby green areas (Figure 2.12).

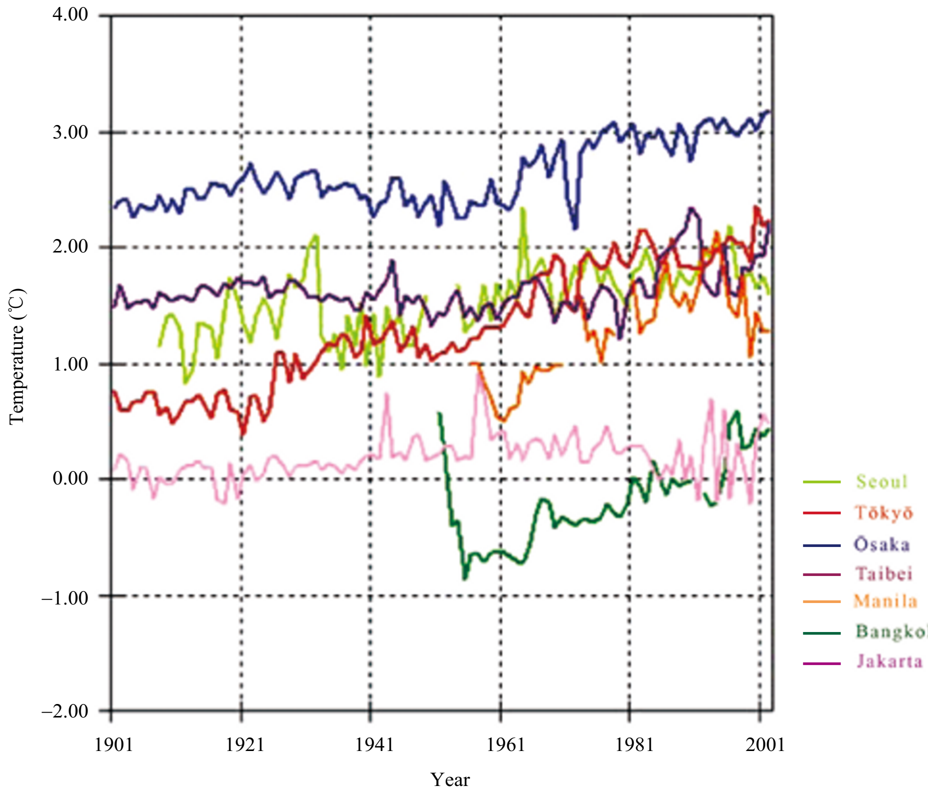


Figure 2.11 Variation in estimated heat island intensity in large Asian cities (Source: Kataoka, 2009)

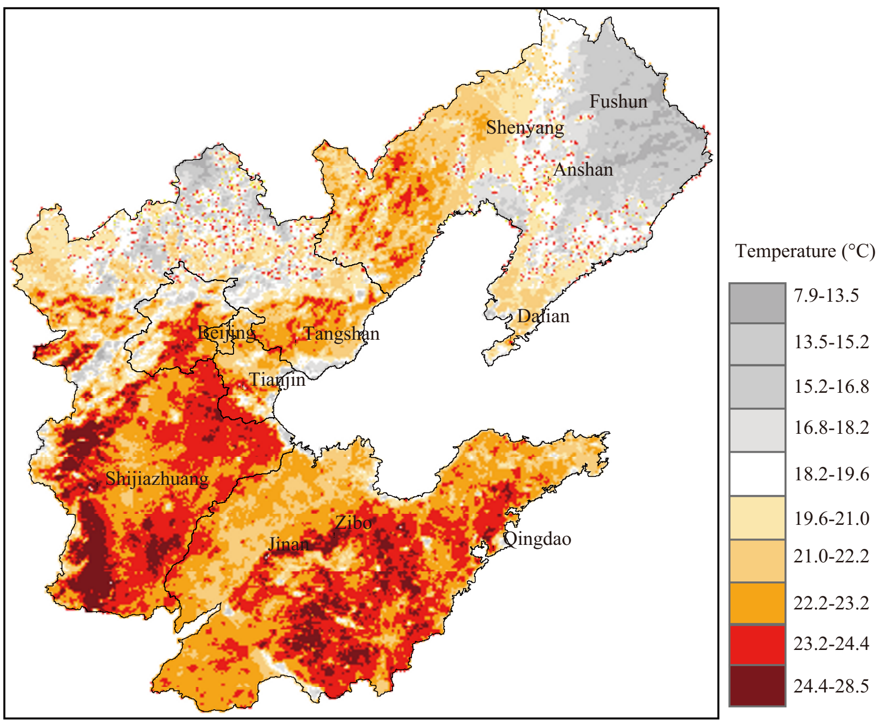


Figure 2.12 Remotely sensed thermal infrared data have demonstrated the land surface temperature can get 2.5°C higher in city center than nearby green areas in east China. Image processed by Yonghong Hu and Gensuo Jia with NASA MODIS data

2.4.3 Urban subsurface environment

Groundwater has become an increasingly important aspect of human life, though its role as part of the urban environment has not as yet been evaluated (Taniguchi et al., 2008). Perhaps the most dramatic and obvious subsurface environmental problem occurring in Asian coastal cities is the subsidence due to excessive pumping of groundwater. Subsidence due to excessive groundwater pumping has occurred repeatedly in large Asian cities as a result of an increase in demand for water resources (Figure 2.13). Compaction of sediments after subtracting pore water in the aquifer is the main reason for the subsidence. The magnitude of the subsidence depends on the drawdown depth of groundwater level, the duration time of the groundwater pumping and physical characteristics of the aquifer (i.e., clay or silt). Changes in reliable water resources from groundwater to surface water supplies have been initiated by government policies in many cases, yet subsidence is still not being prevented in many areas. This has resulted in a serious risk of flooding in many coastal cities in Asia. For example, some sections of Bangkok now flood during each spring tide. Climate change, such as changes in precipitation patterns due to global warming, have resulted in some Asian cities shifting their water resources in the opposite direction, i.e., from surface water to groundwater (Wang, 2005).

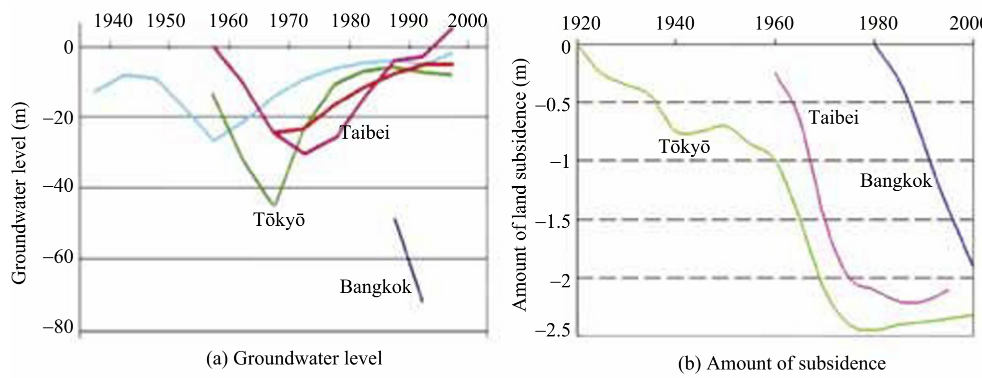


Figure 2.13 Change in groundwater level and amount of subsidence over selected Asia cities in past 20-80 years (Source: Taniguchi et al., 2008)

Groundwater over urban and densely populated areas is at particular risk. The exploitation of groundwater resources is leading to rapid lowering of water tables across China, India, Iran, Pakistan, and the Philippines; and diminished grain harvests due to overexploitation of ground water are reported in many areas across Asia. Poor communities depending on shallow drinking water wells and urban centers such as Jakarta that rely on groundwater are paying the price of too-rapid extraction. Surveys of groundwater used in industrial zones in India and used as a source of urban water in China show that the majority of sources are contaminated. Contamination of groundwater by naturally occurring arsenic has been confirmed in Afghanistan, Bangladesh, India, Nepal, Myanmar, China, Viet Nam, Cambodia, Thailand, Pakistan, and Iran. Estimates from published cases suggest that around 200 million people may be exposed to health risks associated with arsenic-tainted drinking water on a daily basis. Another 129 million people in India and China may be at risk of serious dental and skeletal deformities from drinking water with high levels of fluoride (UNEP, 2007). While arsenic and fluoride are naturally occurring contaminants, the risk of exposure to these contaminants increases as the region becomes more dependent on its groundwater resources.

Another important aspect of the subsurface environment concerns material (contaminant) transport to the coast. Since most Asian megacities are located on the coast, material and contaminant transport by groundwater is a key to understanding present and future coastal water pollution and effects on associated ecosystems (Capone and Bautista, 1985). While the overall flow of fresh groundwater into the ocean is likely no more than about 6% of river runoff, it has been estimated that the total dissolved salt contributed by terrestrially-derived submarine groundwater discharge may reach as much as 50% of that contributed by rivers (Zektser and Loaiciga, 1993). This process will thus affect the biogeochemistry of estuaries and the coastal ocean through the addition of nutrients, metals, and carbon (Hwang et al., 2005). In addition to inputs of terrestrially-derived groundwater, recirculation of seawater through sediments by tidal pumping and other processes can also provide significant biogeochemical inputs and is also considered "submarine groundwater discharge" (Li et al., 1999; Burnett et al., 2003).

The biogeochemical importance of groundwater discharge to the coastal ocean is dependent on several variables, including the amount and type of nutrient enrichment, water column circulation and tidal flushing, and the groundwater flow rate, which is determined by the porosity and permeability of the underlying strata and the hydraulic head. During the passage of terrestrially-derived fluids through sediments in a coastal aquifer, mixing of seawater with fresh groundwater and chemical reactions of the fluids with solid phases will occur. Thus, the emerging fluid is often chemically distinct from both the groundwater and seawater endmembers. Concentrations of nutrients, trace metals, organic carbon, and other components may be considerably higher than coastal ocean waters. Groundwater may have nutrient concentrations several orders of magnitude greater than surface waters either from contamination sources or natural processes.

Flood disasters are now the most frequent and devastating natural disasters in monsoon Asia, with even greater threaten to urban areas. Changes to the Asian monsoon system, by altering flood regimes, may compound the existing challenges of managing in urbanizing regions by altering flood regimes. There are several possible pathways. First, increasing sea levels exacerbate risks of flooding of cities in coastal zone deltas. Second, the increasing frequency of extreme precipitation events is important apropos landslide risks and the risks for settlements in upland areas or sudden the river bank floods in lower flood plains. Third, climate change impacts on melting glaciers in the uppermost reaches or reduced precipitation in inland continental areas. Concurrent changes in land and water use may exacerbate or reduce the effects of changes in climate on disaster risks.

2.4.4 Solid waste

Municipal solid waste is everything collected and treated by municipalities. Only part of it comes from households, the rest is generated by small businesses, commercial and other municipal activities. So it is produced from both consumption and production processes. Like all waste, municipal waste is on the rise and it is growing faster than the population, a natural result of our increasing consumption rate and the shortening of product life-spans. As 1.6 billion Asian city residents enjoy the benefit of rapid economic growth, municipal waste is certainly a major environmental concern.

Solid waste management is an integral part of the urban planning and environmental management. It uses urban infrastructure to ensure a safe and healthy human environment while considering the promotion of sustainable economic growth (Figure 2.14).

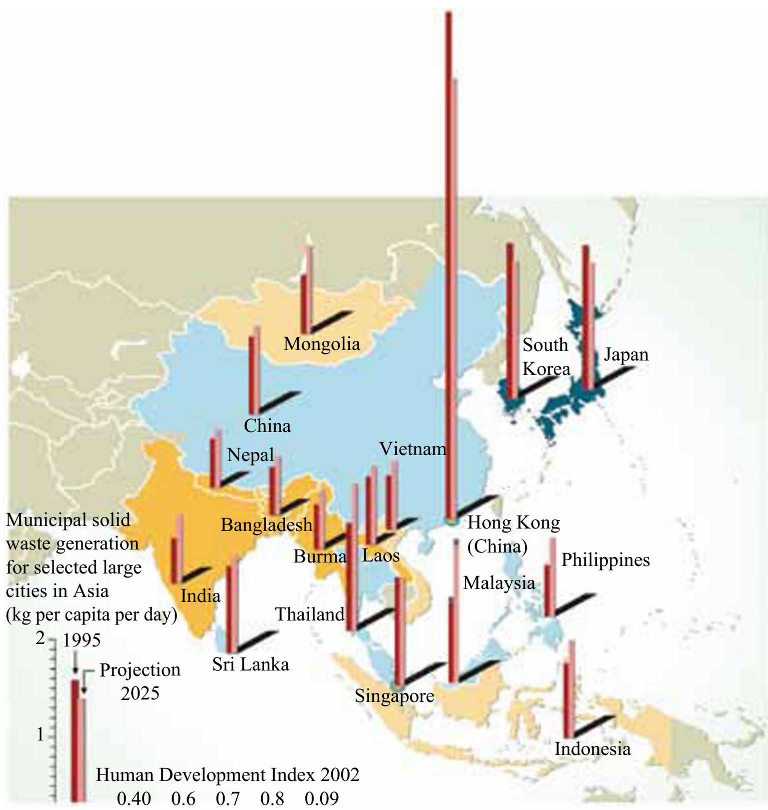


Figure 2.14 Municipal solid waste generation for selected large cities in Asia (Source: UNEP/GRID-Arendal Chart Database (2005). Credit: Philippe Rekacewicz, UNEP/GRID-Arendal)

There are two major issues featured the management of municipal solid waste in Asia, they are traditional/cultural issues and climatic factors. The recovery of reusable items like cloth bags, glass bottles, and metal containers occurs at the household level by the itinerant collectors who generally pay a nominal amount for the material or provide a useful material in exchange. This is found at the middle and lower income levels of the population of which there is a vast majority. This helps in reducing the quantity of refuse generated but bring gross negligence on the part of the generators inducing littering and unmonitored waste.

Climatic factors play another crucial role in the solid waste management. The monsoon effect with intense precipitation is found in south, southeast and east Asia with a wet season ranging from 5 months to almost throughout the year especially in the equatorial regions. Many Asian countries lie in the tropical or sub-tropical zone with a long wet season, and therefore, heat and humidity lead to higher moisture content in municipal waste, thus increase the weight load of the trash cans and treatment plants. In addition, high humidity with heat causes quick decomposition of organic portion of the waste and causes problems in handling and disposal, which directly affects the environmental health of the waste workers and the inhabitants. Such climatic conditions often require daily collection of waste, making the collection system even more expensive.

Rapidly growing populations, rapid economic growth and rise in community living standard have accelerated the generation rate of municipal solid waste causing its management to be a major worldwide challenge. Solid wastes accumulate in Asia and cities and towns with rapid economic growth, lead to increasing challenges to urban environments and human health (Figure 2.14). Particularly in major cities of developing countries, MSW management is a highly neglected area. The quantity of solid waste generation is mostly associated with the economic status of a society. Accordingly, Table 2.2 shows GDP, together with waste generation rates for some of the largest Asian economies (Shekdar, 2009). It clearly demonstrated that waste generation rates are lower for low income developing economies.

Table 2.2 Information on GDP, waste quantity for some Asian economies

Countries/Regions	GDP	Waste quantity
Hongkong, China	37385	2.25
Japan	33010	1.1
Singapore	31165	1.1
Taiwan	31040	0.667
Republic of Korea	23331	1.0
Malaysia	12702	0.5-0.8
Thailand	9426	1.1
China	8854	0.8
Philippines	5409	0.3-0.7
Indonesia	5096	0.8-1
Sri Lanka	5047	0.2-0.9
India	3794	0.3-0.6
Vietnam	3502	0.55
Lao PDR	2260	0.7
Nepal	1760	0.2-0.5

Source:
Shekdar, 2009

Transboundary movement of waste is another increasing solid waste problem. While the production and disposition of waste in Asian cities remain unresolved, the major economies in Asia such as China, India and ASEAN countries have become the destinations of illegal transboundary movement of waste. Especially, air and water pollution caused by illegal transboundary movement of electronics garbage in many Asian countries are getting serious. Asia is now becoming a key destination of international electronic waste (Figure 2.15).

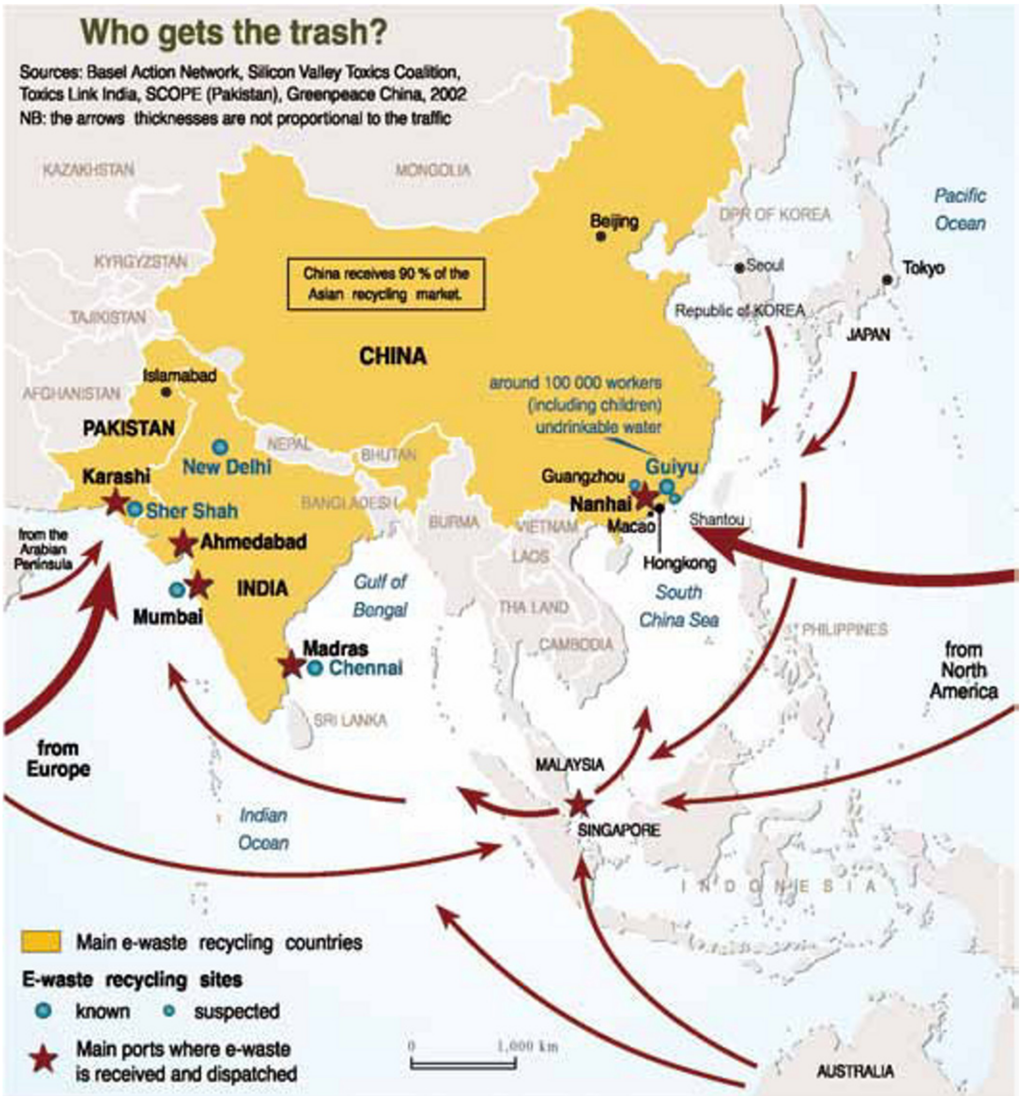


Figure 2.15 Transboundary dumping of e-waste into Asia (Source: UNEP/GRID -Arendal Chart Database (2005)) (Credit: Philippe Rekacewicz, UNEP/GRID-Arendal)

3 Challenges and Opportunities for Better Environment

3.1 Key problems

Generally speaking, Asia is under rapid transition from agriculture societies into industrial economies, though some countries like Japan are already among developed ones (Figure 3.1). Such transitions, featured by urbanization and industrialization, have continuously shaped regional environment for 20-30 years, and will likely last for another half century or so. It is unrealistic to expect major changes of development modes and environment impacts in the near future, and therefore, Asia environment will likely continue to get worse in coming years, despite of improvements in some areas. The economic standard of most Asia developing countries have not yet reached the turning points of so-called Environmental Kuznets Curve (See Box 3.1), which means that they will have to struggle for a difficult balance between economic growth and environmental quality for a long period.

Much of the environmental degradation in Asia occurs as a result of market failures, inefficiency in production and use of energy and resources, lack of ability or cooperation of local governments, lack of integrated planning, and weak environmental regulatory agencies.

Weak environmental regulatory agencies also have a large part to play for environmental degradation in this region. On one hand, environmental protection in the region is regarded as a policy goal to be pursued exclusively within environmental ministries or equivalent agencies. Few countries effectively mobilize other government agencies to this challenging task. On the other hand, although there are so many environmental regulations, they are not fully implemented in many cases. Environmental ministries or equivalent agencies in the region are often lack of real power and necessary facilities to design, implement, monitor, inspect and enforce new effective environmental polices and regulations.

Box 3.1 The Environmental Kuznets Curve

Kuznets predicted that the changing relationship between per capita income and income inequality is an inverted-U-shaped curve. As per capita income increases, income inequality also increases at first and then starts declining after a turning point (TP). In other words, the distribution of income becomes more unequal in early stage of income growth and then the distribution moves towards greater equality as economic growth continues.

There is evidence that the level of environmental degradation and per capita income follows the same inverted-U-shaped relationship as does income inequality and per capita income in the original Kuznets Curve. Now, Kuznets Curve has become a vehicle for describing the relationship between measured levels of environmental quality (for example, concentration of SO_2) and per capita income. This inverted-U-shaped relationship between economic growth and measured pollution indicators (environmental quality) is known as the EKC.

In the history of developed countries, the turning points ranged from 5,000-15,000 USD. The Environmental Kuznets Curve is now widely accepted among economic experts, environmental scientists, and even governments.

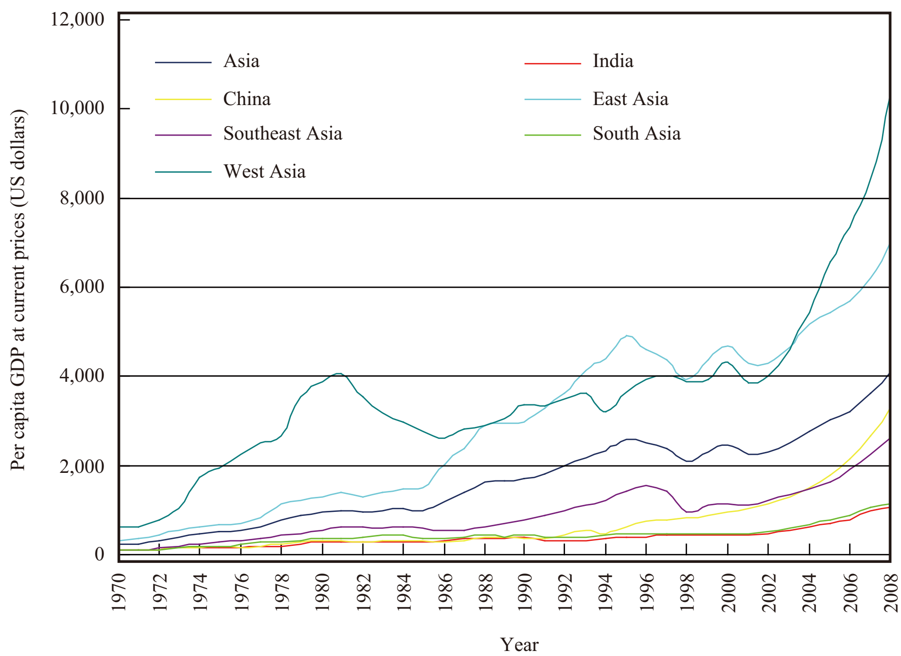


Figure 3.1 Decadal trends of per capita GDP at current prices among Asia sub-regions from 1970 to 2008. Designed by Yaozhi Zhou based on UN data (Source: UN, 2009)

Asia has been heavily dependent on dirty-burning coal to fuel its rapidly growing economy. This coal dominance in the energy mix in developing Asia and inefficiencies in production and use of energy and resources, combined with rapid urbanization and motorization, have led to unprecedented environmental consequences. This situation would worsen because Asia will likely keep rapid economic growth in order to alleviate the poverty of the two-thirds of the world's poor living in the region.

Urban districts development and transportation infrastructure have been expanded at a remarkable rate in many Asia countries in past decades without considering eco-efficiency of energy and material use (Figure 3.2). A few countries are starting to exploit solar and wind energy but centralized, fossil-fuel based electricity infrastructure continues to expand. In most places, new development of sanitation infrastructure and services is based on developed-country models, implying significant environmental footprint. In many cases, new urban planning still follows the old fashions that do not include sufficient treatment facilities for wastewater and solid waste. The hidden environmental and economic costs of these unsustainable patterns of infrastructure development are substantial; pollution and the additional costs of physical infrastructure, as well as high future demand for energy and water, are important cost burdens that compromise sustainability of many Asia countries. Technical and financial barriers exist, but the greatest barrier is lack of awareness and institutions.

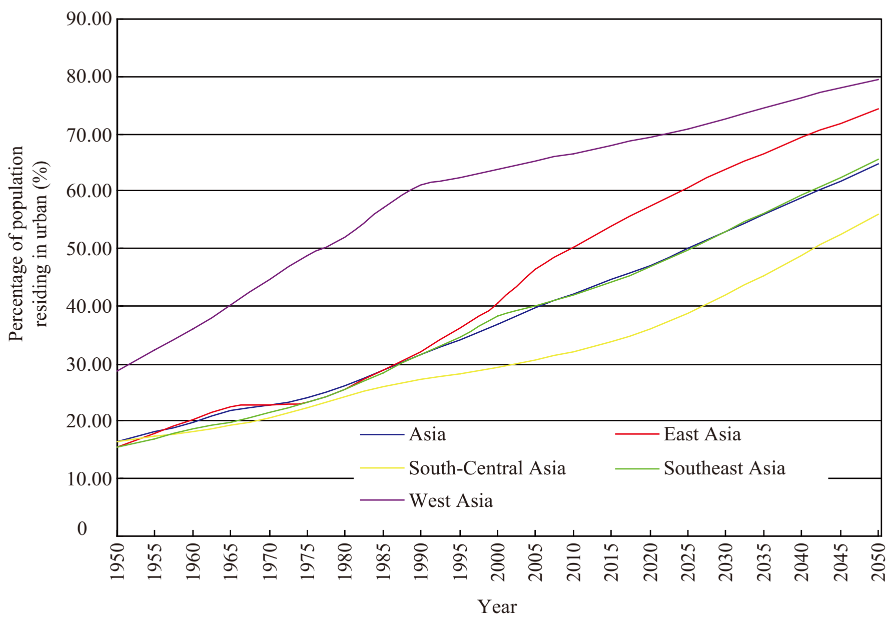


Figure 3.2 Statistical and predicted percentage of Asian population residing in urban areas from 1950 to 2050. Designed by Yaozhi Zhou based on UN data (Source: UN, 2009)

Meanwhile, Asia countries have to face various environmental impacts of climate change and natural disaster, which make regional environmental problems ever worse and more complicated.

Controlling greenhouse gases emission and adapting human settlements to withstand the extreme climatic conditions have become the most formidable challenges of our times. Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades (Figure 3.3) (IPCC, 2007). Adaptation and mitigation actions include technological, institutional and behavioral options, the introduction of economic and policy instruments to encourage the use of these options, and research and development to reduce uncertainty and to enhance the options' effectiveness and efficiency. Opportunities exist to integrate adaptation and mitigation into broader development strategies and policies. However, although there may be synergies between mitigation and adaptation, e.g. planting of trees in urban areas help sequester carbon as they grow and reduces urban heat stress in summer, there also may be conflicts, e.g. dense compact urban forms reduce GHG emissions by facilitating public transit but, in hot-humid regions, the same form will contribute to human discomfort as in

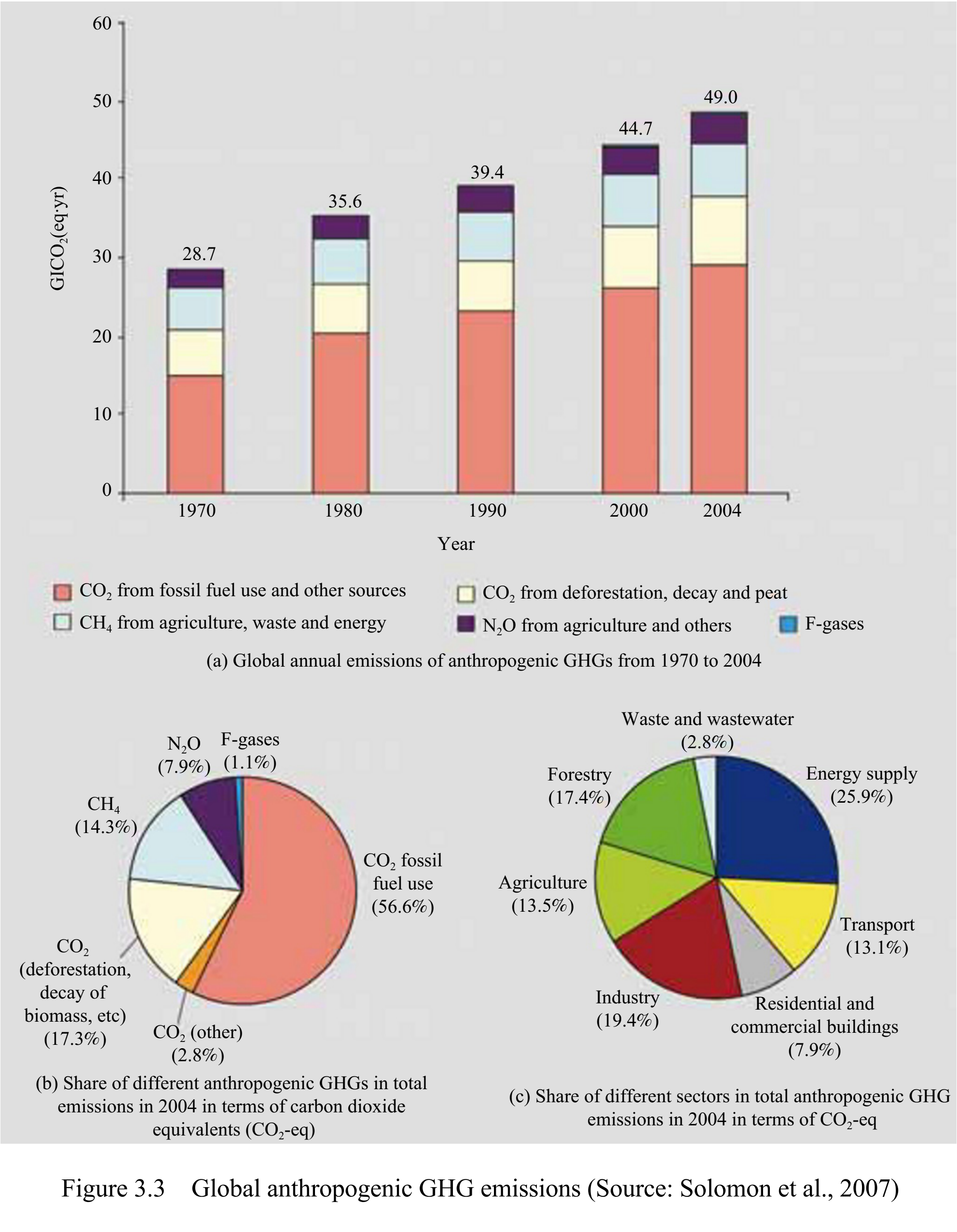


Figure 3.3 Global anthropogenic GHG emissions (Source: Solomon et al., 2007)

such climatic zones, during summers, a tight arrangement of buildings would block the free movement of air so needed to lower body temperature. This apparent paradox poses a conundrum for planners and urban designers at a time when there is urgency to devise strategies to respond to climate change.

Asia is among the most vulnerable regions to climate change. The anthropogenic signal of climate change has been detected in Asia with strong statistical significance, making mitigation strategies a sensible option, especially in South Asia and China, where the highest concentrations of rural poor relying on agriculture reside. The effects of climate change will exacerbate stresses on agricultural production, particularly in low- and mid-latitude countries; will adversely affect wheat productivity in the Indo-Gangetic Plains; will reduce rice yields due to increased night-time temperatures; and will increase demand for water.

Table 3.1 estimates sectoral vulnerabilities for the subcontinental regions of Asia. It is widely accepted, however, that mitigation alone is not sufficient to solve the climate problem; a combination of the two approaches is most effective. In China, for example, a study by Lin et al. (2005) shows that areas of northwest China—such as Inner Mongolia, Ningxia, Gansu, Shanxi, and Shaanxi—are highly vulnerable to major meteorological disasters because of their low levels of development and lack of investment in adaptive measures. In addressing this vulnerability, the study stresses the importance of agricultural insurance, such as risk management, and income transfers to support and protect the agricultural sector, as well as the exploration of the gradual establishment of agricultural insurance policy as an adjunct to assistance provided by the Chinese government in the event of disasters affecting food security. In many instances, reform of existing policies is needed to promote adaptation to climate change. For example, diesel fuel for irrigation pumps in India is highly subsidized, leading to over pumping of water that exacerbates the increase in water scarcity due to climate change.

Table 3.1 Vulnerabilities of key sectors for the subcontinental regions of Asia

Subregon	Food and fiber	Bio diversity	Water resource	Coastal ecosystem	Human health	Settlements	Land degradation
North Asia	+1/H	–2/M	+1/M	–1/M	–1/M	–1/M	–1/M
Central Asia and West Asia	–2/H	–1/M	–2/VH	–1/L	–2/M	–1/M	–2/H
Tibetan Plateau	+1/L	–2/M	–1/M	Not applicable	Information not available	Information not available	–1/L
East Asia	–2/VH	–2/H	–2/H	–2/H	–1/H	–1/H	–2/H
South Asia	–2/H	–2/H	–2/H	–2/H	–2/M	–1/M	–2/H
Southeast Asia	–2/H	–2/H	–1/H	–2/H	–2/H	–1/M	–2/H

Source:
Cruz et al., 2007

As discussed in previous sections, Asia has vast plateaus and high mountains, the largest portion of arid and semi-arid areas, and the longest (approximately 283,188 km) and complex shorelines in the world. Those areas are especially vulnerable to fluctuation of air temperature and precipitation, and rise of sea levels.

Meanwhile, there is a major conflict between rapid economic growth and emission control in Asia. The rapid economic development along with the booming of population in Asia in past 2-3 decades have greatly increased the wealth in the region, but also stimulated the demands for energy and natural resources, and further accelerated the emission of greenhouse gases and environmental pollution.

Clearly, high percentage of rural poor and urban dwellers in Asia are vulnerable to climate change and weak in adaptation and mitigation. Despite of the rapid economic growth and major achievements in combating poverty, the level of poverty in Asia is still very high. By the end of 2007 there were still 1.4 billion world population lived under poverty level (with daily income less than 1.25 USD). Among them, 903 millions (2/3 of the world poorest) lived in Asia-Pacific region. Nowadays, South Asia is still the poorest region in the world (WDI, 2009). The poor population had increased from 470 millions in 1981 to 550 millions in 2005 in South Asia, makes it the only region that had net increase of poverty.

Poor communities can be especially vulnerable, in particular those concentrated in high risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies.

3.2 Responses and actions from various sectors

With increasing environmental deterioration and climate change impacts, actions are essential for managing and reducing their negative impacts. Such actions also offer an opportunity to adjust economic activities in vulnerable sectors and to support sustainable development and poverty reduction. Nowadays individuals, households, communities, businesses, and governments in many Asia countries are taking serious steps to improve our environment and to cope with climate change. Adaptation involves adjustments in natural or human systems in response to actual or expected environmental and climate change impacts to reduce harm or exploit beneficial opportunities. It can operate at two broad levels: building national and local adaptive capacity, and delivering specific adaptation actions. Table 3.2 summarizes major adaptation options that are available and have been practiced in developing countries as reported in UNFCCC (2007).

Table 3.2 Adaptation Options

Items	Reactive/Responsive	Proactive/Anticipatory
Water Resources	• Protection of groundwater resources • Improved management and maintenance of existing water supply systems • Protection of water catchment areas • Improved water supply • Groundwater and rainwater harvesting and desalination	• Better use of recycled water • Conservation of water catchment areas • Improved system of water management • Water policy reform including pricing and irrigation policies • Development of flood controls and drought monitoring
Agriculture	• Erosion control • Dam construction for irrigation • Changes in fertilizer use and application • Introduction of new crops • Soil fertility maintenance • Changes in planting and harvesting times • Switch to different cultivars • Educational and outreach programs on conservation and management of soil and water	• Development of tolerant/resistant crops (to drought, salt, insect/pests) • Research and development • Soil-water management • Diversification and intensification of food and plantation crops • Policy measures, tax incentives/ subsidies, free market • Development of early warning systems
Forestry	• Improvement of management systems including control of deforestation, reforestation, and afforestation • Promoting agroforestry to improve forest goods and services • Development/improvement of national forest fire management plans • Improvement of carbon storage in forests	• Creation of parks/reserves, protected areas and biodiversity corridors • Identification/development of species resistant to climate change • Better assessment of the vulnerability of ecosystems • Monitoring of species • Development and maintenance of seed banks • Including socio-economic factors in management policy
Coastal and Marine Resources	• Protection of economic infrastructure • Public awareness to enhance protection of coastal and marine ecosystems • Building sea walls and beach reinforcement • Protection and conservation of coral reefs, mangroves, sea grass, and littoral vegetation	• Integrated coastal zone management • Better coastal planning and zoning • Development of legislation for coastal protection • Research and monitoring of coasts and coastal ecosystems
Health	• Public health management reform • Improved housing and living conditions • Improved emergency response	• Development of early warning system • Better and/or improved disease/ vector surveillanceand monitoring • Improvement of environmental quality • Changes in urban and housing design

Source:
ADB, 2009; Adapted from UNFCCC, 2007

3.2.1 Industry Sectors

Rapid economic development of Asia developing countries over past 20-30 years has helped millions of people get rid of extreme poverty, which is a significant achievement towards the Millennium Development Goals (MDG). However, the achievement was accompanied with wasteful consumption of energy and raw materials. The increasing demands for energy, water, and materials led to environmental deterioration and rise of greenhouse gas emissions, and put a big shadow on the achievements in social and economic development. Good news is that manufacturers in many Asia countries are making major progress on eco-efficiency and pollution controls.

In September 2009, UNIDO, the Philippines government, UNESCAP, and UNEP jointly organized an international conference on Asia green industry. Senior officers from 22 Asia countries signed an agreement of Manila Declaration on Green Industry in Asia and framework of actions. The declaration urged governments, private sectors, and international organizations work together to strengthen green growth strategies. UNIDO is promoting its Green Industry Initiative, a pattern of industrial development that is economically, environmentally and socially sustainable.

According to the Manila Declaration, Asia countries aim to reduce industrial emissions to the lowest possible level thought clean energy and eco-efficient technologies. It also urged implementation of low carbon strategies among governments, international organizations, private sectors, and science community.

Recent global economic and financial crisis greatly reshaped structure of industrial sectors, and accelerated the development and application of energy efficient technologies and alternative energy industry. This is a very good opportunity for industry upgrades and restructuring Asia industry. Those challenges could push Asia industry to strengthen their competitiveness in global markets as well as to go greener.

China is seriously implementing its low carbon policies for climate change adaptation and mitigation. In 2007, China released the national plan for climate change adaptation and mitigation, and outlined the targets, principles, priority areas, and strategies for actions towards 2020. One of the major tasks listed is reduction of greenhouse gas emission from vehicles. China promised to cut CO_2 emission by 40%-45% per GDP unit by 2020 over 2005 baselines. This is a challenging task for industrial sectors, the most important contributors to economic growth, resources and energy consumptions, and environmental pollutions.

Indian government promised to limit its per capita greenhouse gas emission to equivalent or even lower level of developed countries by increasing industrial energy use efficiency, encouraging use of renewable energy, and introducing clean energy technologies. Euro V emission standard will be applied on four-wheel automobiles by the end of 2010. Indian government also released series of regulations in its current five-year plan (2007-2012) for more environmentally friendly cars on the roads.

The government of Republic of Korea took great efforts on energy efficiency and alternative energy in recent years. According to its 2008 national energy strategic plan, the energy use efficiency in Republic of Korea will be increased by 46% in 2030, an annual increase of 2.6%.

Many other Asia countries are taking similar efforts to achieve more environmentally friendly manufacturing and services. Several major Asia based auto manufacturers, including BYD, Volkswagen China, Honda, and Toyota have accelerated the development and even market sharing of hybrid and electrical vehicles in past five years.

3.2.2 Water resources sector

There is compelling evidence that a substantial increase in global food production is needed to feed growing populations, and to reduce or eliminate situations where people have insufficient food for their daily needs. This increase in production will require more water. At global scale, the agricultural sector uses the vast majority of freshwater resources, and so is a logical target for economizing water use and developing methodologies for growing more food with less water.

Because agriculture and healthy ecosystems can be compatible goals, the major challenge is to improve irrigation for food production by increasing water and land productivity, supporting ecosystem services and building resilience, while mitigating environmental damage, especially within the context of ecosystem-based integrated water resources management (IWRM) approaches.

Since groundwater levels are falling, and aquifer water stores are shrinking in many highly-populated countries, much of the additional water required for agricultural production must come from dammed rivers. While acknowledging the environmental damage and socio-economic dislocation associated with construction of some dams, the building of more dams cannot be dismissed, since they can provide significant sources of water. But, more attention must be directed to understanding and balancing the environmental and socio-economic impacts associated with dam construction and operation against the benefits to be derived from them. Augmenting the resources of water-scarce regions by inter-basin transfer is another established option, although proposed schemes must demonstrate the social, environmental and economic benefits to both the donating and the receiving basins.

While the impacts of increasing water demand for agriculture may be acceptable in countries with ample water resources, the escalating burden of water demand will become intolerable in water- scarce countries. Such situations can be alleviated to some degree by water-scarce countries shifting their food production to "water-rich" ones, deploying their own limited water resources into more productive economic sectors. This would address the need for energy-and technology intensive transport of water to distant areas of demand. Although globalization in the agriculture and related food production sectors already facilitates such changes, these approaches require close cooperation between producing and receiving countries. Better management of marine, coastal and inland waters and their associated living resources improves the integrity and productivity of these ecosystems.

Although there is little scope to expand or develop new fisheries, there is considerable opportunity to improve the management of existing fisheries and food production. Governments, industry and fishing communities can cooperate in reducing fish stock losses by making much needed changes to reduce excess fishing effort, subsidies and illegal fishing.

Aquaculture currently helps to address the issue of food security, and has the potential to contribute further both by increasing fish supplies cost effectively, and by generating foreign income by exporting increased fish production, which can improve local livelihoods. But, aquaculture development to meet food security needs must include species that are not dependent on fish meal and fish oil, and that are palatable to a wide range of consumers.

Controlling many diseases that are either water-borne or closely linked to water supplies depends on the use of specific technological measures, the maintenance or restoration of aquatic ecosystems, and public education and awareness. Technological approaches, such as the construction and operation of cost-effective water treatment plants and sanitation facilities for treating human wastes, provide effective measures against water-borne diseases. Many industrial water pollutants with human health implications also are amenable to treatment with technologies that capture materials from water. These technologies can sometimes recover useful products (such as sulphur) from waste streams. Ecosystem restoration may reduce the incidence of some water-borne diseases, but it can also lead to an increase in the incidence of others. This negative aspect may be countered by improved understanding of the ecological requirements of disease vectors, and incorporating this knowledge into restoration projects.

Traditional approaches, such as rainwater harvesting, can provide sources of safe drinking water, particularly in water-scarce areas or locations that experience natural disasters and other emergencies.

Climate change phenomena, such as erratic rainfall patterns, El Niño episodes, and drought, have exacerbated growing water stress in key economic sectors of the region. In recent years, the region's major rivers have been under threat not only due to diversion to hydropower energy and to freshwater needs of the growing urban population, but also to climate change. Most countries in the region have experienced growing water shortages due to changes in rainfall patterns and the effect of El Niño. Consequently, water quantity and quality have deteriorated. Overexploitation of water resources has depleted aquifers, lowered water tables, and reduced stream flows, which in some cases have already reached ecologically unsafe levels (Arnell, 2004).

To improve the water security situation, Asian countries have used supply-side measures, such as water harvesting technologies and renovation of irrigation facilities, and demand-side measures, including promotion of efficient use of water resources and better water management practices. Damaged irrigation facilities contribute to difficulties in meeting water demands from agriculture. For example, in 2003 a high and significant percentage of irrigation facilities in several districts of Indonesia were damaged. Governments have taken steps to address this by repairing existing facilities and implementing innovative adaptation measures. Farmers in a number of drought-prone districts in Indonesia have been trained to develop rain harvesting technologies to absorb surplus water from irrigation and rainfall. The Government of Vietnam has planned for the extension of small-scale irrigation schemes in Ninh Thuan province. On the demand side, Thailand has promoted the combined use of surface and groundwater resources to maximize the yield of water resources, while farmers in Indonesia and Viet Nam have been trained in the better management of water including efficient and effective use of irrigation water and other water resources (ADB, 2009).

As climate change causes extreme weather events such as floods and storm surges, flood control facilities have been installed and communities have been trained to cope with floods. Southeast Asia has already suffered from floods and storm surges brought on by climate change. Several areas, particularly in the Philippines, Thailand, and Vietnam, are flood-prone, making these countries particularly vulnerable to extreme weather events. In response, flood control and prevention facilities have been put in place in these locations. For example, the Bangkok Metropolitan Administration has established pumping stations in strategic areas of the city to regulate water in canals and rivers that tend to overflow during the rainy season. Water gate facilities have also been installed for flood control as well as for the prevention of saline water intrusion in Thailand. Upgrading of existing drainage systems has been proposed in Vietnam, particularly in the Red River and Mekong River Deltas, and has already been implemented in Singapore. Experience from the Lower Songkhram River Basin in the northeastern region of Thailand also shows that an effective way to prepare for floods is to provide training to the local communities in flood prone areas, for instance, how to build rice storage silos on high ground and how to prepare for moving livestock. Viet Nam is considering a more proactive approach to flood control by establishing flood warning systems for local communities (ADB, 2009). To respond to the increasing water consumption and in order to reduce reliance on water imports, Singapore has recently implemented several projects to expand and diversify its domestic water supply, one of which is reclaiming used water through NEWater technology (Figure 3.4). The NEWater installations currently provide about 15% of Singapore's water consumption and capacity will be increased to meet 30% of Singapore's water needs by 2011.

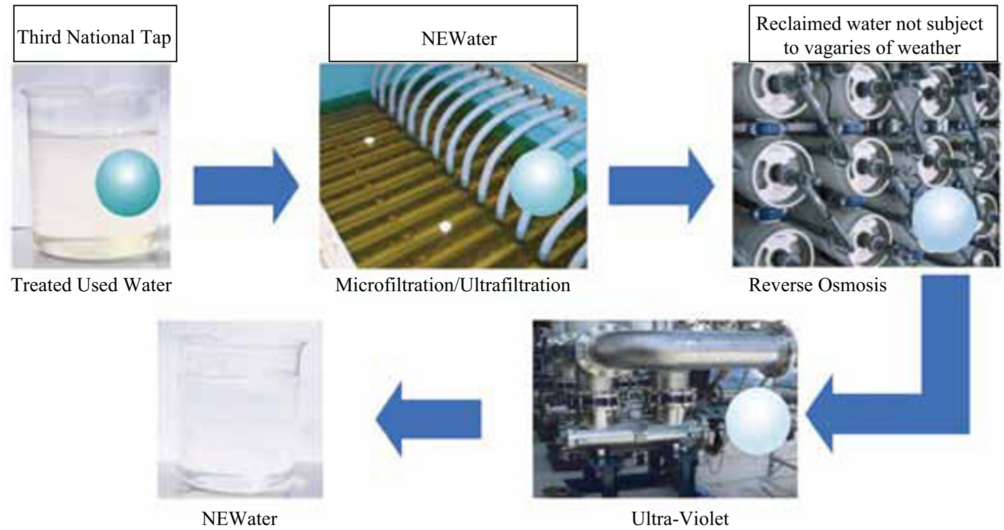


Figure 3.4 NEWater: reclamation of water from waste and sewerage (Source: Ho, 2008)

In Beijing, a 30,000 square-meter housing complex with a rainwater recycling system was constructed to solve the water shortage problem. In the industrial southern city of Shenzhen, officials have introduced measures to use seawater to flush toilets to address water pollution. The Government is constructing a gigantic south-to-north diversion project to take water from the Yangtze River to the dwindling the Yellow River in order to solve the problems of drought in the north and flooding in the south. In hilly Korla City, which gets whipped by sandstorms some 40 days every year. in Xinjiang province, the local government installed a drip line irrigation system to provide water to more than 3,000 hectares of trees planted to address the problem of desertification. (ADB: Asian Water Development Outlook, 2007).

Central Asia will face not only increasing temperatures and rapid recession of glaciers with climate change but more importantly also disruptions to their hydrological cycles that will exacerbate the already critical state of water scarcity and conflicts over water allocation. The rural poor in dry areas will suffer the most from these changes and will require a range of coping strategies to help them adapt to changing climates. Strategies will include changing of cropping systems and patterns, switching from cereal-based systems to cereal–legumes and diversifying production systems into higher value and greater water use efficient options. The latter include judicious use of water using supplementary irrigation systems, more efficient irrigation practices and the adaptation and adoption of existing and new water harvesting technologies (Oweis, 1997). Scope for the application of conservation agriculture in dry areas is thought to be limited by low biomass production but current evidence suggests that even small amounts of residue retention can significantly decrease soil erosion losses. These options will be supplemented by the development of more drought and heat tolerant crop varieties using traditional and participatory plant breeding methodologies and better predictions of extreme climatic events (Thomas, 2008).

3.2.3 Agriculture Sector

The most commonly used adaptive measures in Asia are adjustments to cropping calendars and patterns, changes in management and farming techniques, use of drought varieties, diversified farming, intercropping, and crop rotation. Farm-level adaptation practices are helpful in coping with climate variability, but there is a need for government to strengthen local adaptive capacity by providing public goods and services, such as better climate information and improved impact assessment, research and development on heat-resistant crop varieties, and other techniques, early warning systems, and water-efficient irrigation systems. Innovative risk-sharing instruments for the agriculture sector such as index-based insurance schemes are being developed and tried in Asia.

For the past several decades, agriculture in Southeast Asia has been under considerable environmental pressure due to increasing demands for food, feed, and industrial crops. The growing population and increasing industrialization have triggered intensification of agricultural production to meet growing demands. However, the productivity of major crops has declined in many parts of the region due to increasing average temperatures, resulting in water shortage and heat stress, erratic rainfall patterns that have affected yields and the planting season, frequent typhoons with strong winds causing soil erosion, and flooding that has destroyed many production areas through inundation and siltation (Naylor et al., 2007).

In addition, rising sea levels have reduced arable land through soil salinization. Agriculture is one of the most climate-sensitive sectors in the region and has been hurt by the multifaceted impact of climate change. Farmers across Southeast Asia have a long record of adjustment of farm management practices and cropping techniques to cope with the impacts and variability of climate change. The adaptation measures include changing cropping calendars and patterns (for example, from rice-rice to rice-maize cropping pattern to optimize the use of available water for crop growth); improved farm management; and use of drought-resistant and heat-resilient crop varieties. In Vietnam, future forecasts suggest there will be a need to change rice crop sowing dates and management procedures to optimize rice yields under changing climate conditions. In the northern part of Vietnam, the sowing date of spring rice will be earlier by 15–25 days while the sowing date of summer rice will be 20–25 days later (ADB, 2009). With climate change, the rice growing period in Vietnam will be expanded. Farmers in Thailand have also adopted similar adaptation practices, as well as intercropping, diversified farming, and variation of crop rotation patterns.

It was projected the frequency of food production shortfalls could double in many of the key crop growing regions of Russia by the 2020s and triple by the 2070s because of changes in the frequency of dry periods

(IPCC, 2007). These shortfalls may propagate throughout Russia because of the dependence of most of Russia on the key crop growing regions for food imports, and because of the increased likelihood of simultaneous shortfalls in many of the food export regions. Such increased risks are likely to require significant adaptive measures in the agricultural system. Since climate change scenarios tend to show that much of Russian territory is getting wetter and warmer, the adaptation options and practices in the agriculture could expand rain-fed agriculture to new territories. For example, areas of the Far East and southeastern Siberia which now have very low potential productivity may be able to grow maize, pearl millet and sorghum under the climate conditions of the 2070s.

It is suggested that the most effective adaptation measures include crop shifting, water saving irrigation, and no-till farming in agriculture sector, stocking rate reduction based on lowered carrying capacity in livestock management, as well redistribution of land use options among sectors. Many adaptation practices originated from local knowledge are successful, including seasonal enclosure of rangeland and plantation of indigenous shrubs.

3.2.4 Forestry Sector

In the forestry sector, common adaptation practices include reforestation, afforestation, and improved forest management; establishment of early warning networks; use of appropriate silvicultural practices; awareness raising of forest fire prevention; and monitoring of degraded forests. Early warning systems and awareness-raising programs should be enhanced for the vulnerable communities to better prepare for potentially more frequent forest fires as a result of climate change. Furthermore, aggressive public–private partnerships for reforestation and afforestation should be pursued to offset forest and biodiversity losses due to the adverse effects of climate change and extreme climatic events.

Many research suggests that biological sequestration of carbon can play an important role in reducing greenhouse gases (GHG) emissions through activities such as slowing the rate of deforestation, increasing the establishment of forests on old agricultural or degraded lands, and improving the management of existing and future timber (Metz et al., 2001). Tavoni (2007) stated that forestry is an important abatement option, and that its inclusion into an international policy agreement can have a profound effect on the global costs of a climate policy, allowing a free saving of 50 ppmv in 2100, corresponding to 1/4°C. Forest sequestration actions in the first half of the century, mainly from avoiding deforestation, could contribute one-third of total abatement effort, and could provide additional benefits throughout the entire century. Forest sinks have the potential to reduce the price of traded carbon permits, and the overall cost of the policy in terms of income losses, by half.

Southeast Asia grows one of the three major tropical rain forests in the world, and has 203 million ha of forestland (as of 2005). In the past several decade, forestlands have been affected by increasing temperature, heat stress, and drought, which cause forest fires and consequently loss of tree species and degradation of forests. Forest fires count among the main factors contributing to biodiversity and forest loss in Indonesia and the Philippines, and normally occur during El Niño years. To cope with the fire risk, the provincial government of Central Kalimantan in Indonesia has used climate information to develop an early warning system on the likelihood of fire outbreaks. This system can, 2 or 3 months in advance, inform local government or the communities affected about conditions expected in the coming season, allowing them to prepare for the outbreaks of fire. In a season where a prolonged dry spell is expected, the local government warns farmers not to engage in burning to clear land. To encourage farmers to follow instructions, local governments have established an incentive system to reduce fire activities in high-risk years. Similar early warning systems, together with awareness-raising programs, adjustment in silvicultural treatment, and construction of fire barriers, have also been planned in other parts of the region, including the Philippines and Vietnam. Thailand has already felt the impact of forest loss, mainly due to unpredictable rainfall, more frequent and prolonged droughts, flash floods, as well as hotter summer days and nights. This is crucial because forests in Thailand also have important ecological functions, especially in regard to water regulation and microclimate (ADB, 2009).

The Chinese government launched in 1999 the “Grain for Green Program”. The objective of this program was to increase the forest cover on steep slopes in the landscape by planting trees and sowing grasses on former cropland. The program was a massive investment by the central and local governments. By the end of 2005 the program was implemented in an area of 87,000 km^2 in which about 400–600 million trees were planted. Regional soil erosion and sediment delivery rates may be expected to decrease more than 1.2% per year because of the non-linear relation between land cover change and soil erosion. Since most of conversion from arable land to forest took place on the steepest slopes in the landscape a 1.2% conversion per year which was induced by the program may lead to a 10% or more yearly reduction of the annual sediment volume delivered to the main rivers in the Shaanxi province (Zhou et al., 2009).

From 2000-2005, average annual net gain of forest cover in China was 40,000 km^2, as estimated by FAP Global Forest Resource Assessment (2005). The forest gain is mainly due to afforestation, landscape restoration, and natural forest expansion. Some of the effective approaches have contributed to recent forestry achievement in China, including a new Forest property right regulation in 2009, eco-tourism and forest by-products industry in national parks and state forests since mid 1990s, and long-term free lease of wildland to farmers and companies for afforestation use only (Figure 3.5).

(a) Coniferous forest recovering after transformed timber industry into ecotourism and forest by-products companies in Mohe, northeast China

(b) Urban greens are systematically built in major cities like Beijing in China

Figure 3.5 Conservation of natural forests and development of urban forests in China (Photo credit: Gensuo Jia)

In recent years, China started to encourage major cities to develop urban forests and compete for title of "green city" (Figure 3.5). Urban forests are managed for multiple purposes, including recreation, protection of water sources, biodiversity conservation, atmospheric CO_2 sequestration, air pollution reduction, and others. Cities located in different parts of the country may emphasize different urban forest functions. Due to the heavy air pollution in most Chinese cities, however, all of the trees and forests in a city are expected to have a high capacity to retain dust and absorb SO_2, NO_2 and other pollutants. Now several Chinese cities, e.g. Changchun, Nanjing and Guangzhou, have a forest cover of more than 40 percent. China plans to expand the cover of urban forests and trees to 45 percent in 70 percent of its cities by the year 2050.

3.2.5 Health Sector

In the health sector, a number of reactive adaptation measures exist, including rebuilding and maintaining public health infrastructure, coordination with relevant organizations, and establishing green and clean areas. However, a more proactive approach, such as establishment of early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs has to be adopted or extended to better deal with the health impacts of climate change.

Figure 3.6 summarizes the main pathways by which climate change can affect population health (McMichael et al., 2006). Several main environmental manifestations of climate change are shown in the central section. The right-hand boxes, from top to bottom, entail an increase in complexity of causal process and, therefore, in the likelihood that health effects will be deferred or protracted. Most of the diverse anticipated health consequences are adverse, but some would be beneficial. Milder winters would reduce the normal seasonal peak mortality in winter in some temperate developed countries, and warming or drying in already hot regions would reduce the viability of mosquitoes.

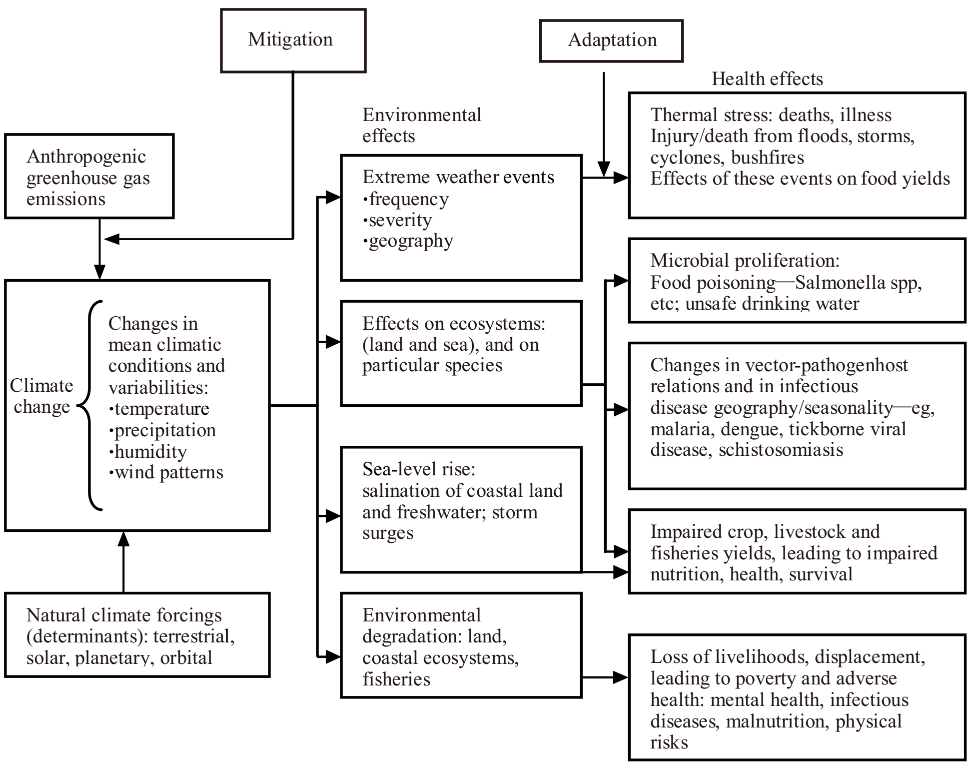


Figure 3.6 Schematic summary of main pathways by which climate change affects population health (Source: McMichael et al., 2006)

The health impacts of climate change will not be distributed uniformly, and the distribution of the most severe health burdens is almost inverse to the global distribution of greenhouse gas emissions. The accumulated reservoir of greenhouse gas emissions overwhelmingly originates from wealthy, industrialized countries in temperate climates, whereas predicted health effects are highly concentrated in poor countries that typically already suffer the worst health. The profound health inequities that climate change creates for the world's poorest citizens present a special challenge to those concerned with global health (Michael et al., 2008).

Adoption of adaptation measures to vector-borne disease carried by mosquitoes, such as dengue, are under way in the region. For instance, the Ministry of Health in Thailand campaigns to control dengue. Advice on control and avoidance measures is passed on to villagers via health workers, village leaders, and the media. Some good housekeeping measures such as regular emptying of all refuse containers and avoiding direct exposure to mosquitoes are being implemented. However, more proactive and aggressive policy initiatives require better information. Most programs to manage these diseases in Indonesia are reactive rather than proactive. Nevertheless, efforts have been made to develop an early warning system for disease outbreaks by looking at patterns in climate data (Sasmito and BMG Team, 2006). This system is expected to assist local health officers in setting up anticipatory management of possible disease outbreaks. However, up to now, such systems remain rudimentary and their potential has not yet been fully utilized.

Adaptation should be seen as a part of the region's sustainable development strategy. Asian countries have already made significant efforts to implement adaptation measures to minimize the impacts of climate change. However, most adaptation measures implemented to date have been reactive rather than proactive, autonomous rather than well-planned, and largely developed to address climate variability rather than climate change. The current level of adaptation is still inadequate to cope with the future challenge of climate change. Only few countries have developed adaptation plans while others are still in the process of finalizing them; and despite the urgent need, many countries lack the resources and the financial capacity to do them on their own. The region has recognized the importance of monitoring climate change, but the efforts made so far are still inadequate to enable proper, long–term planning.

3.3 Solution and strategies based on local knowledge

The rapid increases of industrial production and per capita income in past decades have greatly modified the lifestyles and consumption patterns of Asia population, especially among the young generations. Evolving urban lifestyles increasingly reflect globalizing consumption patterns characterized by energy and resource-intensive and high waste-producing consumption patterns. While many countries have yet to completely meet basic needs, the growth of western style consumption accompanying income rises represents a critical threat to environmental sustainability and conflict with the traditional cultural values of many Asian societies, which have shown great harmony with the nature over thousands of years. Urban lifestyles imply expanded water and energy demand, expanded transportation infrastructure needs, and increased waste production. New waste streams reflect changing consumption patterns, including bottled drinking water, e-waste and packaging from processed food. Demographic, income and lifestyle changes result in smaller, but more energy-intensive households.

People are increasingly demanding and being able to afford personal modes of motorized transport of all kinds, particularly where transport policies and underdeveloped mass transit infrastructure indirectly promote their use. The numbers of passenger cars, for example in use in some fast-growing economies of South and South-East Asia have more than doubled from 1990 to 2002. This has implications for energy use—transport by truck can use 16 times more energy than transporting the same volume of material by rail. Meanwhile, bicycles that used to be the dominant personal transport mode are now significant declined in many newly developed urban areas in Asia. In many cities, bicyclers now hard to find safe bike lines they used to ride on because lines have been expanded for automobiles. Riding a bike became dangerous when they have to move among fast driven cars.

Simple lifestyles and steady family structure in Asia are environmentally friendly. Human consumption is an important driving force for greenhouse gas emission and environmental pollution, therefore, to some extent, human life style shapes the future of planet Earth. Due to their relatively simple consumption patterns and material saving life styles, Asia population has much lower ecological footprint than many other regions. Household dynamics influence per capita consumption and thus biodiversity through, for example, consumption of wood for fuel, habitat alteration for home building and associated activities, and greenhouse gas emissions (Liu et al., 2003). More children choose to live with their parents to form relatively larger family size in Asia, which helps reduce per capita consumption of energy and resources.

Meanwhile, nature worship, i.e. animism and harmony between man and nature plays an important role in climate change adaptation and environmental protection in Asia with long and diverse history. Ancient philosophy that views everything in Nature as having an indwelling spirit/soul, including the plants, rocks, waters, winds, animals, humans, and other life forms. Animism is the foundation of shamanism and has been considered the earliest form of human religion on planet Earth. At the core of the Dongba religion in Southeast Asia is the belief that man and nature are two brothers born of two mothers and the same father. Stories describing the heavenly revenge that befalls humans who hunt too many animals or cut down too many trees are found throughout Dongba literature. Therefore, traditional Asia culture encourages protection of natural environment and save of natural resources, which is still very valuable in modern society for in climate change adaptation and environmental protection.

Religion believes and local knowledge seem very effective for vegetation protection in the region. Xiemenke Bayer is a Mongolian herdsman lives in an isolated small village, Wulanquanji located in the Ulan Buh Desert. His family have been there for century since his grandfather moved in 90 years ago. He is a secondary school graduate, but he is always proud of his half-year training experience on land management in Beijing about ten years ago. He told us that he and his neighbours found several hectares of a "holly trees" in the desert about 20 years ago and decided to protect them since then. They believed that these trees are unknown anywhere else and are god's bless to his village. They were surprised by the strong survival ability of the tree despite of decades of severe desertification, therefore believed they can protect the village and the residents as long as they were there. With his guide we located the trees sparsely distributed among sand dunes. Roots were eroded by wind for many trees, but they all grown well. After a quick taxonomy check, we recognized that they are *Rhamnus erythroxylon*, a common small tree species distributed in northwest China. However, the religion believes of the villagers greatly helped protection of the woodland, and therefore land itself.

Many Asia countries like China have achieved climate change mitigation based on both technology transfer and local techniques. Those efforts include:

(1) Rise of energy use efficiency. As calculated on the year by year comparison, during the period of 1991 ~ 2005, an accumulated 800 million tce of energy were saved by economy restructuring and energy efficiency improvement, which is equivalent to a reduction of 1.8 billion tons of CO_2 emissions, using China's 1994 emission factor of 2.277 tCO_2/tce.

(2) Optimizing energy mix by developing low-carbon and renewable energy. In 2005, the utilization of renewable energy in China equaled to 166 million tce (including large hydropower), accounting for 7.5% of China's total energy consumption in that year, equivalent to a saving of 380 million tons CO_2 emissions.

(3) Launching national wide tree-planting and afforestation campaign and enhancing ecology restoration and protection. Estimated by relevant experts, from 1980 to 2005, a total of 3.06 billion tons CO_2 absorption was achieved by afforestation, a total of 1.62 million tons CO_2 absorption by forest management, and 430 million tons of CO_2 from deforestation were saved.

(4) Effectively controlling the growth rate of population through family planning. Since the implementation of the family planning program, over 300 million births have been averted nationally by 2005. According to the average per capita emissions from the IEA statistics, the averted births have resulted in an annual reduction of CO_2 emissions by about 1.3 billion tons in 2005. It is a significant contribution that China achieved in the fields of controlling world population and mitigating GHG emissions.

4 Environmental and Climate Change Policies Towards Sustainability

4.1 Overview of national regulations and regional cooperation

More and more governments of Asia countries are seriously increasing priority level of environmental regulations in past two decades, especially in recent years. In most countries' national legislations and institutions have reduced the use of ozone-depleting substances, slowed losses of forest cover and reduced air pollution, and particularly in some newly developed mega-city areas in coastal regions. These developments reflect significant improvements in environmental performance at national and regional scales, particularly with respect to pollution control.

However, legislations and institutions designated for limiting energy consumption and solid waste through improving eco-efficiency of the production and consumption patterns are greatly delayed, though so-called low carbon development is increasingly highlighted by many Asia governments. In other words, the national policies of many Asia countries focus on short-term actions to improve environmental performance rather than long-term plans and policies to improve environmental sustainability.

At regional and sub-regional levels, environmental regulations and climate changes acts have been released by several regional organizations and multi-national mechanisms, such as ASEAN, the Shanghai Cooperation Organization, the 10-3 forum, etc. For example, ASEAN clear air act and climate change agreement may lead to common action against regional environmental and climate change issues. However, environmental and climate change are often not priority issued to be concerned in regional cooperation and regulations.

Since the implementation of the Kyoto Protocol in early 1990s, most Asia countries have released their national regulations to mitigate climate change. So far, all Asia countries but Armenia and Palestine have rectified the United

Nations Framework Convention on Climate Change (UNFCCC), and most of them have submitted their national reports to UNFCCC. Months before the Copenhagen meeting, many Asia countries have expressed their strong willingness towards low-carbon solutions. China has just released its strategic plan for climate change adaptation and mitigation (2008) and put energy efficiency and carbon footprint as top priority in national and provincial planning. Indonesia has backed a U.N. scheme that could curb deforestation in return for billions of dollars in carbon credits, while India and China have snared the highest number of U.N.-backed clean-energy projects that also yield carbon credits. Emerging economies in Asia were more likely to use the financial crisis to help them shift into low-carbon development than developed countries. Asia has three of the world's top five greenhouse gas emitters—China, India and Japan, plus industrial powers Australia and Republic of Korea as well as Indonesia, where deforestation and forest fires are a major source of planet-warming pollution. Therefore, Asia regional and national climate policies have major impacts on global efforts on climate change mitigation.

Nowadays, all the major emitters in Asia understood they needed to act on climate change, but each differed in their approaches. China sees climate change issue as a important part of its sustainable development strategies and even a source of prosperity. Climate change issue is now highlighted on environmental legislations from national to local levels. However, some other countries were worried about imposing extra costs on its industries during a recession, and reluctant to act. It is still very clear that poorer nations will not commit to emissions curbs unless rich countries do much more to rein in carbon pollution and pay for adaptation and the transfer of clean-energy technology.

Asia countries are working more closely in recent decade than ever before to cope with regional environmental deterioration and climate change issues through sub-regional organizations and multi-lateral mechanisms. Some of the most important regional cooperation mechanisms are discussed here.

4.1.1 TEMM

China, Japan and Republic of Korea are situated in Northeast Asia and share the atmospheric, marine and natural environment. Recent years have seen rapid economic development in Northeast Asia, with continued growth expected. At the same time, various environmental issues have emerged, and how to achieve sustainable development, through initiatives such as green growth/green economy, has now become a crucial issue. Though the three countries have greatly varying economic and social conditions, they share the common task of having to address national, regional and global environmental issues taking into account their national circumstances.

Thus, the inaugural Tripartite Environment Ministers Meeting (TEMM) among China, Japan and Republic of Korea, was held in 1999, to launch the three countries' cooperative efforts for the environment. To date, the three countries have promoted and implemented cooperation, including information exchange, joint research, and joint projects, etc., regarding various domestic, regional and global environment issues. These efforts have played a major role in the region's environmental management and made contributions to improving the global environment.

At the TEMM 11 which was held in Beijing, China, in June 2009, the Environment Ministers from the three countries reached an agreement on the ten priority cooperation areas for future tripartite environment cooperation as follows:

(1) Environmental education, environmental awareness and public participation;

(2) Climate change;

(3) Biodiversity conservation;

(4) Dust and sandstorms;

(5) Pollution control;

(6) Environment-Friendly society/3R/sound resource recycle society;

(7) Transboundary movement of E-Waste;

(8) Sound management of chemicals;

(9) Environmental governance in Northeast Asia;

(10) Environmental industries and technologies.

The leaders of the three countries met at the Second China-Japan-ROK Summit Meeting held in Beijing in October 2009, and released the "Joint Statement on Sustainable Development among the People's Republic of China, Japan and the Republic of Korea", in which the leaders endorsed the ten priority cooperation areas and instructed the Environment Ministers of the three countries to develop a joint action plan in the stated ten priority areas for adoption at the TEMM 12 in 2010.

4.1.2 EANET

Acid deposition is not limited by national boundaries and therefore cooperation at the regional and international level is required to effectively address this problem. In Europe, it was successfully achieved through the activities under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). As pointed out in Agenda 21 adopted by the United Nations Conference on Environment and Development in June 1992, "the programs (in Europe and North America) need to be continued and enhanced, and their experience needs to be shared with other regions of the world". The Acid Deposition Monitoring Network in East Asia (EANET) was established in 1998 as a regional cooperative initiative to promote efforts for environmental sustainability and protection of human health in the East Asian region.

EANET's outlines are to create a common understanding of the state of the acid deposition problems in East Asia, to provide useful inputs for decision making at local, national and regional levels aimed at preventing or reducing adverse impacts on the environment caused by acid deposition, to contribute to cooperation on the issues related to acid deposition among the participating countries.

Currently there are 51 of acid deposition monitoring sites in the EANET network (20 remote, 12 rural and 19 urban). Of these 51 sites conduct wet deposition monitoring, 39 conduct air concentration monitoring. Data and information for ecological impact studies are currently collected from 14 inland aquatic monitoring sites and 16 soil and forest vegetation monitoring sites. All the sites follow a standardized set of methodologies for site selection, sampling and chemical analyses to ensure technical conformity within the network.

4.1.3 GMS

In 1992, Greater Mekong Subregion Cooperation (GMS) established. The members include Cambodia, China, Laos, Myanmar, Thailand and Vietnam. GMS achieved substantial progress and has become the most influential and successful mechanism in the region. In 1995, the GMS confirmed the environment as one of main areas of cooperation.

The first GMS Environment Ministers' Meeting was held in Shanghai in May of 2005. This EMM endorsed the The GMS Core Environment Program and Biodiversity Conservation Corridors Initiative (CEP-BCI), strives at achieving the vision of a poverty-free and ecologically rich GMS.

Implementation of the various components of Greater Mekong Subregion, Core Environment Program and Biodiversity Conservation Corridor Initiative Phase I (2006-2011) has resulted in substantial gains in mainstreaming environmental considerations in GMS developments. Specifically, the program: ① initiated the establishment of biodiversity corridors and sustainable management regimes in which enhanced environmental management, ecosystem connectivity and livelihood improvement strategies for local communities were implemented in six pilot sites; the outputs were improved livelihoods and maintenance and/or enhancement of biodiversity conservation and carbon offset services. ② piloted three Strategic Environmental Assessments (SEAs) in the Vietnamese hydropower sector, Cambodian tourism sector and the GMS North South Economic Corridor that led to a regional tourism SEA in the North South Economic Corridor (NSEC). ③ strengthened institutional capacities within the environmental ministries and sectoral agencies to carry out national environmental performance assessments (EPA) and Spatial Multi-Criteria Analysis (SMCA) for land use management in all six GMS countries for 2008 and 2009. ④ piloted innovative benefit sharing and sustainable financing mechanisms. ⑤ consolidated spatial and temporal data at different levels (BCI pilot site, landscape/provincial, national and subregional) to assess and monitor environmental performance.

The next Phase II of CEP-BCI will link up with the new GMS Strategic Framework 2012-2022 currently under preparation. The key focus will be on second-generation cooperation extending beyond infrastructure-based connectivity, into areas such as coordination, harmonizing or integrating policies, regulations, standards, procedures and/or institutions to reduce barriers to movement of goods, services, capital and people. The CEP-BCI Phase II will support GMS countries' to upgrade their development planning and management systems in line with international best practices.

4.1.4 ASEAN Environmental Cooperation

The ASEAN Leaders adopted the Declaration of ASEAN Concord II on 7 October 2003 to establish an ASEAN Community by 2020. The Declaration calls for the establishment of the ASEAN Community comprising three pillars, namely ASEAN Political and Security Community (APSC), ASEAN Economic Community (AEC), and ASEAN Socio-Cultural Community (ASCC) that are closely intertwined and mutually reinforcing for the purpose of ensuring durable peace, stability, and shared prosperity in the region. At the 12th ASEAN Summit on 13 January 2007 in Cebu, the Philippines, the ASEAN Leaders affirmed their strong commitment to accelerate the establishment of the ASEAN Community by 2015, as reflected in the Cebu Declaration on the Acceleration of an ASEAN Community by 2015. At the 14th ASEAN Summit, the ASEAN Leaders signed the Cha-am Hua Hin Declaration on the Roadmap for an ASEAN Community 2009-2015. The Roadmap for an ASEAN Community 2009-2015 is composed of the ASEAN Political-Security Community Blueprint, the ASEAN Economic Community Blueprint, the ASEAN Socio-Cultural Community Blueprint and the Initiative for ASEAN Integration (IAI) Work Plan 2 (2009-2015).

The Blueprint for the ASEAN Socio-Cultural Community (ASCC Blueprint) ensures that concrete actions are undertaken to promote the establishment of an ASEAN Socio-Cultural Community (ASCC). ASEAN's commitment to environmental protection is particularly reflected in the ASCC Blueprint. Cooperation on environmental protection among AMS as well as with the ASEAN Dialogue Partners shall therefore be guided by the ten priority areas of regional importance and the relevant actions contained in the ASCC Blueprint as follows:

(1) Addressing global environmental issues.

(2) Managing and preventing transboundary environmental pollution.

① Transboundary haze pollution;

② Transboundary movement of hazardous wastes.

(3) Promoting sustainable development through environmental education and public participation.

(4) Promoting environmentally sound technology (EST).

(5) Promoting quality living standards in ASEAN cities/urban areas.

(6) Harmonizing environmental policies and databases.

(7) Promoting the sustainable use of coastal and marine environment.

(8) Promoting sustainable management of natural resources and biodiversity.

(9) Promoting the sustainability of freshwater resources.

(10) Responding to climate change and addressing its impacts.

In addition to the above ASCC Blueprint actions on environmental cooperation and in the other relevant sectors under the ASCC Blueprint, the APSC Blueprint and the AEC Blueprint also contain actions that are related to, or has an impact on environmental cooperation, and therefore should be taken into consideration in fostering cross-sectoral collaboration in line with the holistic concept of sustainable development, i.e. encompassing environmental sustainability, economic growth and social development.

4.1.5 East Asia Summit (EAS) Environment Ministers Meeting

The Meeting was attended by the Environment Ministers or their representatives of the 10 ASEAN Member States, namely Brunei Darussalam, Kingdom of Cambodia, Republic of Indonesia, Lao People's Democratic Republic, Malaysia, Union of Myanmar, Republic of the Philippines, Republic of Singapore, the Kingdom of Thailand, Socialist Republic of Viet Nam, and Australia, People's Republic of China, Republic of India, Japan, Republic of Korea, and New Zealand. Inaugural EAS Environment Ministers Meeting was held in 2008 in Vietnam which provided them with a timely opportunity to exchange views on various issues relating to the environment, in particular actions contained in the Singapore Declaration on Climate Change, Energy and the Environment adopted by the EAS Leaders at their Third Summit in November 2007. The Ministers also emphasized that the Inaugural EAS Environment Ministers Meeting was an important initial step: ① to actualize the visions of the EAS Leaders on environmental cooperation, noting that ASEAN as the driving force working with other participating countries in the EAS. ② to discuss ways and means to put these ideas into practice through regional cooperative efforts and activities. The main theme of the Meeting was "Achieving Environmentally Sustainable Cities in East Asia".

4.1.6 Environmental Cooperation in Shanghai Cooperation Organization

In June 2001, Shanghai Cooperation Organization was formally established in Shanghai. Now, member countries include China, Russia, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan. The member countries have reached consensus in natural resources exploitation and environmental protection in 2003. In 2004, the summit meeting adopted the Tashkent Declaration, including the content of "taking environmental protection and reasonable and effective utilization of water resources as the cooperation agenda within the framework of the organization". In 2005, in order to respond the Tashkent Declaration, the environmental sector of six member countries decided to organize the environment ministers meeting in appropriate time. So Shanghai Cooperation Organization started the communication activities in environmental corporation in the same year. In 2005, the members established the government working group and organized four times of expert meeting of environmental protection during 2005-2008. The member countries began to develop the draft document on environmental cooperation of the Shanghai Cooperation Organization.

4.2 Lessons and progresses from past decade

In the past decade, most Asian developing countries experienced favorable economic development as well as probably greatest environmental challenges in region's history. While some achievements have been made, more problems remain to be solved.

It is normally easier to reduce pollution from point sources such as chemical factories and to get rewarded in many cases. On the other hand, reducing water pollution from non-point sources such as agricultural production and domestic sewerage, and groundwater contaminating sources such as sewerage systems and landfills is increasingly problematic as environmental pressures grow in most of Asia. Poor water quality continues to hinder the ability of Asia countries to meet rising demand for water (Figure 4.1).

(a) Central public transport hub in Chibuya, Tokyo support millions of passenger flows each day and greatly released surface traffic

(b) Pedestrian streets in newly developed in many major Asia cities like Shanghai are encouraging people go around without a car

Figure 4.1 Development of green transportation in Asia cities (Photo credit: Gensuo Jia)

One good news is that most Asia countries have developed their regulations and facilities for reuse, recycle, and reduction of solid waste, especially packaging. National legislations and government sponsored programs play most important roles in waste management, while grassroot activities often only fill the gap where no formal recycling programs exist. Some countries, such as Japan, Korea, China, Singapore, have initiated waste sorting and recycle projects. Far fewer countries have initiated waste minimization and dematerialization. The true costs of waste disposal are not usually reflected in the policies of Asia developing countries. Therefore, neither manufacturers nor consumers have strong economic incentive to reduce waste.

Adaptation actions have been taken in a number of key sectors where climate change impact is most visible or damaging in Asia, including water resources, agriculture, forestry, coastal and marine resources, and health. These actions, however, are mostly reactive, rather than proactive; in many cases, their implementation is scattered rather than systematic, and isolated rather than integrated; and measures often offer short-term benefits, rather than long-term solutions. Asia needs a more proactive, systematic, and integrated approach to adaptation in many key sectors that is cost-effective and offers durable and long-term solutions.

Adaptation inherently suffers from several market failures. The market failures arise because of uncertain information associated with large scale and long-term investment such as climate proofing of building and defensive infrastructure; the positive spillover and the public goods nature of certain adaptive measures such as research and coastal protection; and the need for coordination among many multiple stakeholders. As a result, private markets and autonomous actions alone will not lead to an adequate level of adaptation. Many adaptation measures need to be driven by public policy and government interventions.

A closer look at the trends of CO_2 emissions as compared with GDP trends shows that some countries, e.g. China and Malaysia, have managed to slow the rate of CO_2 emissions while their economies continue to grow. In others countries, notably Thailand and India, the growth of CO_2 is tightly linked to GDP growth. Pollution control as a key determinant of environmental performance is also found to improve as incomes increase, as shown by the Environmental Performance Index (http://www.yale.edu/esi).

Recent lessons from various countries have depicted that the formulation of mitigation strategies cannot be exclusively top-down as it requires social, political, and cultural acceptance and sense of ownership. An interactive, participatory process, involving local communities, produces best expected outcomes concerning mitigation, preparedness, and recovery. Climate change in isolation is unlikely to be the major impact issue. Climate change is likely to have significant impacts mainly by interacting with other stresses on sustainable development (Wilbanks et al., 2007). An emerging consensus is that there is a need to move towards the "mission" of the International Strategy for Disaster Reduction which aims at building disaster resilient communities by promoting increased awareness of the importance of disaster reduction as an integral component of sustainable development, with the goal of reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental disasters.

4.3 Going forward

4.3.1 Environmental governance

Environmental Governance can be understood as the conglomeration of different mechanisms and systems that promote environment protection and conservation through an array of rules and regulations in any given country. Due to the rapid industrial growth and its unfavourable consequences all around the world, the concept of Global Environmental Governance has gained prominence in the recent years, as the effective handling of environmental issues and management of natural resources are important for the very survival of humanity.

Governments, intergovernmental and nongovernmental organizations, major groups, the private sectors and civil societies, individually or collectively, have a role in environmental governance. At the international level, multilateral environmental agreements have been increasingly playing an important role. Regional organizations and bodies provide forums for policy development and implementation in regions. The scientific community plays a specific role in providing a basis for scientifically sound and informed decision-making.

4.3.2 Strengthen public awareness

The environmental pollution led to a situation wherein livelihoods of millions of people are being affected. The enormity of the problems clearly indicates that the state alone cannot tackle the problem on its own and it needs to be supported in addressing the same. In order to attain sustainable development, there needs to be a multi-pronged approach and one among them is increased participation of civil society in environmental decision making process in local, regional and international arena. Agenda 21, devotes chapter 27 to NGOs and the strengthening of their role 'as partners for sustainable development; Principle 10 of the Rio Declaration gives a clear indication that public participation (broadly including Civil Society Organizations) is vital to handle the environmental issues in the best possible way. Civil society operating capacity remains too limited, while their numbers are constantly expanding, and furthermore the geo-graphical focus of civil society activities is noticeably confined to specific areas.

While it is very evident that the civil society organizations are continuously growing to be diverse and vibrant, their level of participation in international environmental governance is still negligible and one of the factors that contribute to the same may be the enormity of the problems that need to be addressed at the national level. There are signs of improvement in the policy and enabling environment for their operation at national level and international level. And in Asia its development should also be stressed.

People who perceive that they are vulnerable are more likely to respond to warnings and undertake protective measures (Michael and Fasil, 2001). Public awareness and education initiatives are essential in order to engage people successfully. Therefore, efforts must be undertaken to inform the public of the possible impacts of climate change, the steps necessary to reduce GHG emissions, and measures necessary to adapt to changes already took place. Good news is that a range of Asian companies are increasingly describing strategic business initiatives to curtail carbon emissions. Meanwhile, climate change and environmental issues are increasingly shown on mainstream media and in school classrooms throughout Asia in recent years, and more and more NGOs actively working on rising public awareness.

4.3.3 Capacity building

The future success of greenhouse gas mitigation in Asia will largely depend on energy efficiency and energy conservation; reforestation efforts; integration of climate mitigation policies; domestic air pollution abatement; and integration of policies relating to agriculture, land use and energy systems.

Action to mitigate climate change is becoming synonymous with action on improving energy security and is increasingly compatible with economic objectives; this was clearly stated at 2009 Copenhagen Climate Change Conference by leaders of many Asia countries. For Asia countries, energy efficiency is not only an issue of CO_2 emission control, but more importantly, it is an issue of technical renovation and sustainable production. Improving energy efficiency and changing consumption patterns is becoming more urgent, and more feasible, in light of the recent elevated energy prices, the proven high returns on investments in energy conservation and efficiency, and the availability of financing options offered by international emissions trading, joint implementation and the Clean Development Mechanism (CDM) of the Kyoto Protocol. Currently, technical and financial barriers are still the major problems that prevent Asia developing countries from greatly rising energy use efficiency and cutting CO_2 emission in short-term. Industrial sectors often reluctant to import expansive technologies or run power-consuming pollution control facilities, unless there is strong support from governments or international organizations.

Under the terms of the UNFCCC, developed countries have agreed to "assist the developing country parties that are particularly vulnerable to the adverse effects of climate change in meeting the costs of adaptation to those adverse effects". There is a commitment in principle from developed countries to provide assistance to help meet the costs of adaptation to climate change, which goes beyond normal development assistance, and perhaps carries additional moral weight than promises to help combat desertification or loss of biodiversity. This is because climate change is clearly linked to the much higher level of greenhouse gases emitted by developed countries. As such, they have a responsibility to help mitigate the impacts on vulnerable developing countries. There is a growing divergence between the priorities determined in global negotiation of multilateral environmental agreements and the priorities of specific countries, especially poor developing countries, as clearly demonstrated in 2009 Copenhagen Climate Change Conference. Developed and developing nations have to work together to face the common challenges, either within Asia or globally.

Uncertainty persists about the possible extent and rate of climate change, and about what the most effective adaptation responses might be. While more research and development on these and related questions have potential value, lack of knowledge is not a primary constraint. The broad direction to be taken is clear.

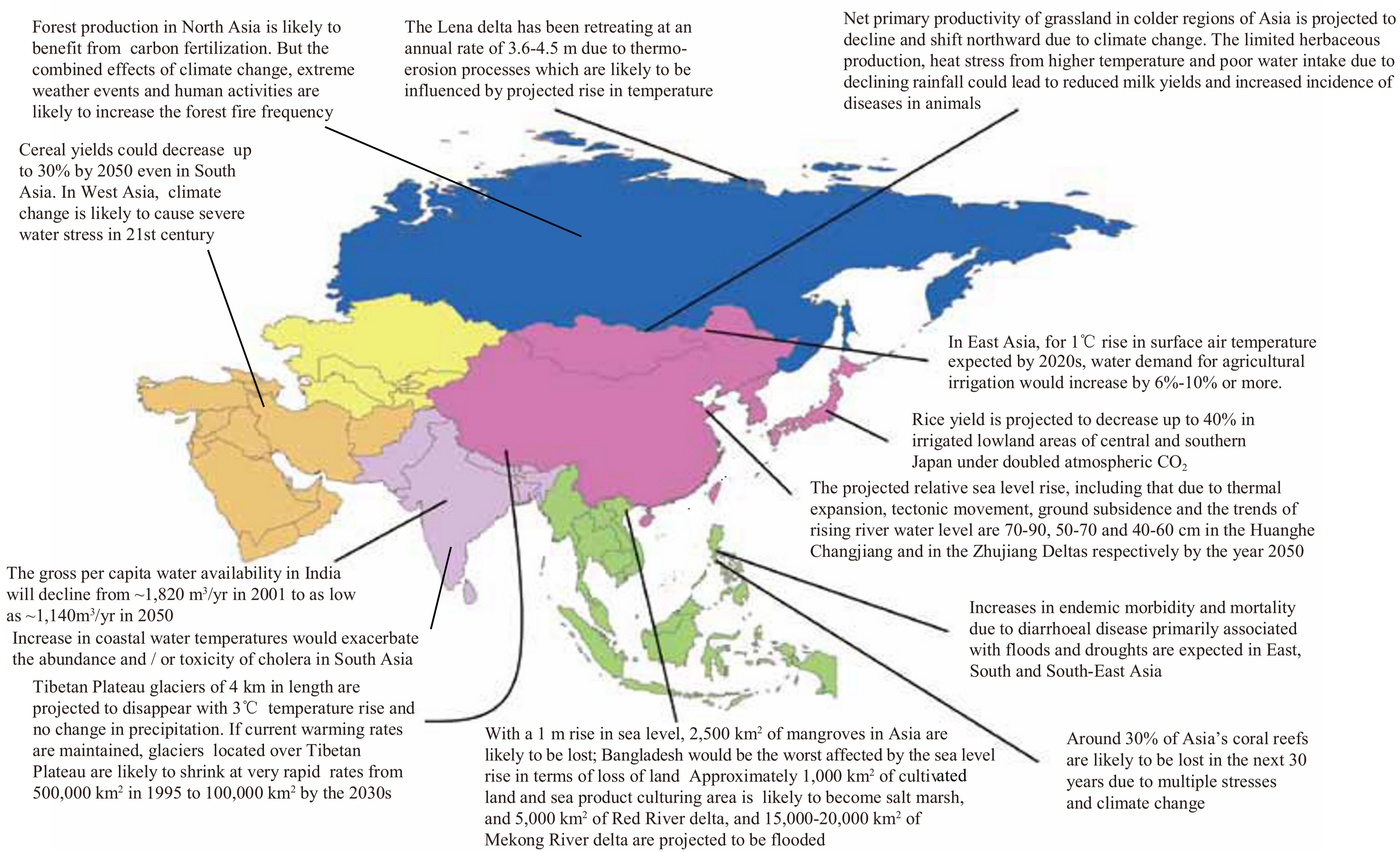


Figure 4.2 Hot spots of key future climate impacts and vulnerabilities in Asia (modified from IPCC, 2007) (Source: Cruz et al., 2007)

At the same time, rapid economic and social development that is driving environmental changes might also reduce certain kinds of vulnerabilities (Figure 4.2). The range of technologies available to governments and communities has grown tremendously. Institutional innovations like insurance and better accountability, data and information systems, better communication infrastructure and better observation systems could further reduce key vulnerabilities or be the basis of adaptation to future changes in the monsoon in Asia and the global environment. But involuntary risks are also modified and shifted by development.

To further achieve in environmental management and climate change mitigation, Asian countries badly need to build their fundamental capacities in areas such as:

(1) Improving information infrastructures, especially regarding climate change damages at a variety of scales, characteristics of response actions, and estimations of sensitivities and coping capacities.

(2) Improving the capacity to account for and consider the significance of uncertainties, including recording different levels of confidence of data entries.

(3) Improving the capacity to model technological change/learning as a dimension of climate change response capacities over time.

(4) Developing effective, analytically robust approaches to reflect interregional, cross scale, and intergenerational interactions.

(5) Experimenting with a wider range of approaches to modeling, including gaming and simulation modeling.

4.3.4 South-south cooperation

South-South cooperation is undertaken by developing countries as a part of partnership and solidarity for development rather than development assistance or aid. In the process of their development, developing countries accumulate valuable lessons, skills and expertise that can be valuable for other developing countries. These skills and capabilities are often more appropriate than those available from industrialized countries due to shared development challenges faced by them. The appropriateness of developing country skills and technologies arises from a number of reasons.

(1) The developing country skills are evolved in an environment of similar factor endowments, for example, labor abundance and relative capital scarcity. Hence, developing country technical solutions may be labor intensive rather than automated solutions available from industrialized countries.

(2) The developing country technological solutions are evolved in an environment of relatively poorer infrastructure and hence may be more appropriate compared to those available in industrialized countries.

(3) The developing country expertise may be more attuned to similar geoclimatic conditions (for example tropical rather than temperate climate) compared to those in the industrialized countries. It is for this reason perhaps that SSC is generally concentrated within the regions.

(4) Technologies and expertise available in developing countries are likely to be scaled down to scales more appropriate to the size of markets in develop-

ing countries compared to mass production skills in industrialized countries.

(5) The technologies and expertise available from developing countries are likely to be cost effective having been adapted in view of low income consumers in developing countries.

South-South cooperation can play a significant role in the fight against climate change. Many developing countries are adopting low-carbon development paths, backed by renewable energy and energy efficiency. Countries can share these experiences, policies and adaptation technologies.

For promoting South-South Environmental Cooperation, China and ASEAN member states have the effective dialogue and cooperation on environment. With the rapid economic development, both China and ASEAN member states suffer from growing pressure on environmental protection. The environmental problems facing China and ASEAN are various, ranging from air and water pollution, deforestation, soil erosion and degradation to loss of biodiversity and climate change. Given the trans-boundary nature of environmental issues, the actions taken by individual countries alone are not sufficient to tackle the challenge. The regional cooperation provides a complementary and effective solution to the improvement of environment. China-ASEAN cooperation is one of the major cooperation mechanisms in the region. Over the past decade, the China-ASEAN cooperation which covers a broad range of areas has been significantly enhanced. In terms of environment, a breakthrough was made at the 11th China-ASEAN Summit in 2007, in which leaders agreed to adopt environmental protection as the 11th priority area of China-ASEAN cooperation. Based on the consensus reached at the summit, the Ministry of Environmental Protection of the People's Republic of China (MEP), ASEAN Secretariat jointly developed the "China-ASEAN Strategy on Environmental Protection Cooperation 2009-2015", which was endorsed during the 10+3 (ASEAN, China, Japan and Republic of Korea) Environmental Ministerial Meeting in 2009. As indicated in the Strategy, the goal of the ASEAN-China environmental cooperation is to build up a resource-conserving and environmentally friendly society, and enable the participating countries to better pursue sustainable development.

To better promote China-ASEAN environmental cooperation, at the 11th China-ASEAN Summit in 2007, the Chinese Premier Mr. Wen Jiabao announced that China would establish and host a China-ASEAN Cooperation Center for Environmental Protection (CACE) in Beijing.

With the approval of the Chinese government, China-ASEAN Cooperation Center for Environmental Protection was launched in March 2010. Aiming at becoming a unique and an open platform for promoting regional cooperation on environment between ASEAN member states and China, CACE is located in Beijing and operates independently under the guidance and with the support of the Ministry of Environmental Protection of the People's Republic of China.

4.3.5 Local knowledge

Impacts of climate change are likely to be severe in the Asia-Pacific region, but adaptive capacity is weak in most countries and communities. As much of the adaptation is site-specific and has to be developed at the individual and community level, it is crucial to harness local knowledge in designing adaptation strategies. However, local knowledge was rarely taken into consideration by policy makers in designing adaptation strategies and very few institutional mechanisms exist to mainstream traditional coping and adaptation mechanisms. a shift in paradigm from "top-down strategy" to a "bottom-up participatory approach" and designing a policy framework comprising both "scientific" and "indigenous" adaptations as well as "planned" and "autonomous" adaptations, is vital to facilitate future adaptation to climate change.

As discussed in earlier sections, Asia people have developed very effective ways dealing with the environment in their thousand-year of history. These ways are still useful in modern society. Transfer of advanced technologies from developed countries has long been considered as the critical ways for mitigating climate change and environmental pollutions. However, those imported technologies are often expansive and complicated to use in developing countries, especially in rural areas. On the other hand, many "low-tech" technologies developed locally thought long-term practices are very effective, low cost, and easy to learn. They are based on experience, often tested over centuries of use, and entails many insights, perceptions and intuitions relating to local culture and the environment. Local knowledge embodies place-specific experience on climate change, so it allows better appraisal of climate risk factors in production decisions.

Generally speaking, Asia environment will likely continue to be deteriorated due to the high environmental pressures resulting from expanded consumption and production activities in coming decades, and some areas will be worsened with climate change. The net result is declining environmental sustainability. Meanwhile, major progresses in environmental improvement can be expected as income and public awareness continuously rise in many parts of the continent, especially in East Asia and Southeast Asia.

Rapid economic growth has enabled significant economic and social progress in the region, but we are still far away from achieving the goal of sustainable development. Developing economic growth patterns which do not compromise environmental sustainability are an urgent global priority, and are the most relevant to the dynamic Asia.

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