As part of a global exercise on Vulnerability Assessment of Freshwater Resources to Environmental Change, initiated by UNEP, the report tracked the changes in freshwater resources over last five decades for five major selected river basins in Northeast Asia: Changjiang (Yangtze) River, Huanghe (Yellow) River, Orkhon River, Songliao Basin and Tuul River. Available freshwater resources continue to decline as a result of excessive withdrawal of surface- and groundwater, as well as decreased water runoff from the land surface attributed to climate change. Use of freshwater for agriculture, industry and energy has increased markedly over the last 50 years. Changes in the hydrosphere can hinder achievements of the clean water, health and food security targets of the MDGs, and damage ecosystem health and services as well as having socio-economic impacts.

Contact

Director, Division of Early Warning and Assessment
P.O. Box 30552, Nairobi 00100, Kenya
Tel: (+254) 20 7623231 • Fax: (+254) 20 7623943
Email: dewa.director@unep.org • Web: www.unep.org

www.unep.org
United Nations Environment Programme
P.O. Box 30552, Nairobi 00100, Kenya
Tel: (+254) 20 7621234
Fax: (+254) 20 7623927
E-mail: uneppub@unep.org
Web: www.unep.org

UNEP

978-92-807-2948-1
DEW/1101/BA

FRESHWATER under THREAT NORTHEAST ASIA

UNEP

FRESHWATER under THREAT

NORTHEAST ASIA

Vulnerability Assessment of Freshwater Resources to Environmental Change

United Nations Environment Programme

Peking University

Mongolia Water Authority

ISBN: 978-92-807-2948-1
JOB No.: DEW/1101/BA

United Nations Environment Programme
P.O. Box 30552, Nairobi, Kenya
Tel: (+254) 20 7621234
Fax: (+254) 20 7623927
http://www.unep.org

Cover Photograph Credits
Background: Tom Murphy / WWI / Still Pictures
Left/Middle/Right: Mantang Cai

FRESHWATER UNDER THREAT

NORTHEAST ASIA

Vulnerability Assessment of Freshwater Resources to Environmental Change

Changjiang River Basin

Huanghe River Basin

Orkhon River Basin

Songliao River Basin

Tuul River Basin

Yi HUANG

Mantang CAI

Jinhua ZHANG

Dambabazar CHANDMANI

Jialiang CAI

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

PEKING UNIVERSITY, CHINA

УСНЫ ХЭРЭГ ЭРХЛЭХ ГАЗАР

MONGOLIA WATER AUTHORITY

Acknowledgements

This study was supported by United Nations Environment Programme (UNEP), with funding from the Belgian Government through the Belgian Development Cooperation Fund. Special thanks are due Jinhua Zhang, Salif Diop and Patrick M'mayi from UNEP, for their valuable assistance and guidance in the overall formulation of the project.

This project was a joint collaborative effort of Peking University of China (PKU) and the Water Resources Institute of the Mongolia Water Authority (MWA), with the two teams working closely to produce this report. All the efforts of the following individuals from two groups are appreciated, including: Yi Huang, Mantang Cai, Dambabazar Chandmani, Jialiang Cai, Sanduijav Narantuy, Xi Zhao, Yingheng Fei, Yuanqing Chao, Xiaolan Ao, Bo Peng, Yadamtsoo Tsedenbaljir, Qing Yang, Xiao Li, and Weishuang Zheng.

Thanks are also due the following experts that contributed invaluable information and constructive comments and feedback to this sub-regional report: Binghui Zheng, Chazhong Ge, Yuanhang Zhang, Xiaoyan Tang, Huaicheng Guo, Dagva-Ochir Saikhanjargal, Mukand Babel, Donghui Wen, Weizhong Wu, Shuguang Xie, Zhiji Huang, He Yin, and Feng Zhou.

We are also indebted to numerous organizations that assisted us in finding the data required for this report, including the Institute of Environmental Sciences, Chinese Research Academy; Ministry of Water Resources, National Bureau of Statistics, Ministry of Health, and Ministry of Foreign Affairs of the People's Republic of China; National Bureau of Statistics, Mongolia; and other universities, agencies and institutions in the region.

This sub-regional report draws on data published by many other organizations. These sources are specified where appropriate in the text, as well as identified in the Reference List.

Foreword

Executive Director
United Nations Environment Programme

Freshwater resources – essential for life on Earth and the achievement of the Millennium Development Goals (MDGs) – are under growing pressure from social, economic and environmental factors including population expansion, overexploitation of land resources, increasing pollution, climate change and unsustainable management practices. Integrated Water Resources Management (IWRM) has been recognized as one of the top priorities for society to be able to respond to these challenges. This is especially important in Asia where water resources are scarce in many countries. A good understanding of how water resources are vulnerable to environmental change is essential for informed decision making.

This publication – the product of a collaborative effort between the United Nations Environment Programme (UNEP), Peking University of China and the Water Resources Institute of the Mongolia Water Authority – provides an integrated vulnerability assessment of freshwater resources in Northeast Asia. Assessments were carried out for five key river basins in the sub-region: the Changjiang River Basin (China), the Huanghe River Basin (China), the Song-Liao Basin (China), the Orkhon River Basin (Mongolia), and the Tuul River Basin (Mongolia), which together cover a land area of almost 4 million square kilometres, and are home to more than 1 billion people. In Northeast Asia, about 350 million people have benefitted from efforts to achieve the Millennium Development Goal on access to safe drinking water since 1995. However, more than 700 million people in the five basins still have inadequate access to safe drinking water and improved sanitation.

The report also confirms the significant link between climate change and water availability with solid scientific evidence and data in the selected basins. Global warming will further affect the water balance in these basins and exacerbate extreme events of drought and floods.

There are no easy generic solutions. Innovative basin-level policy interventions are urgently needed for each river basin to reduce vulnerability to environmental change, and optimize services for future development. In this context, it is our hope that this report will be a useful resource for decision makers in China and Mongolia to make informed decisions in IWRM, and for other stakeholders to understand the important and urgent need for IWRM in Northeast Asia. This publication will be accompanied by an interactive electronic version allowing users to easily access a greater range of information at basin and sub-basin scales.

Achim Steiner
United Nations Under-Secretary General and Executive Director
United Nations Environment Programme
October 2008

Acronyms and Abbreviations

ADB	Asian Development Bank
CRB	Changjiang River Basin
CSY	China Statistics Yearbook
DP	Development pressures
D. P. R. Korea	Democratic Peoples Republic of Korea
EH	Ecological health
FAO	United Nations Food and Agriculture Organization
GDP	Gross Domestic Product
GIS	Geographic Information System
GOVCN	Central People's Government of People's Republic of China
HRB	Huanghe River Basin
IDWS	Improved drinking water supply
IMF	International Monetary Fund
IS	Improved sanitation
LRB	Liaohe River Basin
MC	Management challenges
MDGs	Millennium Development Goals
MFA	Ministry of Foreign Affairs, People's Republic of China
MH	Ministry of Health, People's Republic of China
MSY	Mongolia Statistics Yearbook
ORB	Orkhon River Basin
P. R. China	People's Republic of China
R. Korea	Republic of Korea
R&D	Research and development
RB	River basin
RS	Resource stresses
SHJRB	Songhuajiang River Basin
SLB	Songliao River Basin
TRB	Tuul River Basin
TWSS	Tap water service system
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and cultural Organization
US	United States
US$	United States dollars
VI	Vulnerability Index
VIS	Vulnerability Index System
WB	World Bank
WUGDP	Water use per uint GDP

Symbols

°C	Degrees Centigrade
km	Kilometre
km^2	Square kilometer
km^3	Cubic kilometer
kw	Kilowatt
mm	Millimeter

Table of Contents

List of Tables

List of Figures

Executive Summary

Introduction

Water resources are normally defined as the total quantity of water that can be readily use by human beings. Coincident with population expansion and the evolution of human society, water demands are continuously increasing. At the same time, quickly expanded human activities have negatively influenced the health of freshwater systems, contributing to the vulnerability of freshwater resources systems. Thus, wise water resources management is one of the major challenges constraining our ability to achieve sustainable development, and water resources management, as an important component in the ecosystem management goals in the development agenda of all countries. The initiative on vulnerability assessment of freshwater resources under the context of the climate and socioeconomic change will definitely contribute to better decision making in the water sector.

The study of this sub-region was generally carried out in two steps: (1) a general analysis of the status of the water resources in the sub-region; and (2) a comprehensive analysis of five selected major river basins in the sub-region, with the goal of a better understanding of the freshwater resources, in terms of state, drivers and pressures causing the vulnerability, and the impacts resulting from the changed states and responses for overcoming the main threats at the river basin scale. In considering the nature of water resources management, this exercise was based on a conceptual framework designed to examine four important components: (1) water resources formulation from natural hydrologic process; (2) development and use of water resources for maintaining human well-being and socioeconomic development; (3) water resources for maintaining ecological/environmental functions of a river basin; and (4) management capacity.

As part of an UNEP's global initiative on assessment of vulnerability of freshwater resources under a changing global climate, this report summarizes the results from an in-depth vulnerability assessment of freshwater resources in the Northeast Asia sub-region, including a general introduction to the sub-region and the main characteristics of its freshwater resources, including all the countries in the sub-region, and an in-depth synthesis of vulnerability assessment of the freshwater resources, based on the results from the 5 selected river basin assessment case studies, which are attached to this report as appendixes.

Physical Features

The Northeast Asia sub-region covers a vast territory, with a total land area of 11,764,596 km^2 (4,542,336 mi^2), It borders on the Pacific Ocean, and with a total coastal line of 86,199 km

(53,562 mi), and more than 22,000 islands. It is comprised of 5 countries, including People's Republic of China, Mongolia, Japan, Republic of Korea and Democratic Peoples Republic of Korea.

The region exhibits diverse topographic features, including 5 basic topographic types (plateaus; plains; basins; mountains; hills). With mountains as the main topographic type (accounting for 54.6 per cent of the total land area), the Northeast Asia sub-region is generally characterized by steep slopes and rugged landform. There are 3 topographic steps from the west to the east, with its height gradually decreasing.

The sub-region exhibits a rich combination of temperature-precipitation patterns, including continental, Oceania and monsoon climates. It can be divided into 5 temperature zones on the basis of the annual accumulated temperature (with daily mean temperature higher than 10 ^{o}C [50 ^{o}F]): (1) tropical zone; (2) sub-tropical zone; (3) warm temperate zone; (4) middle temperate zone; and (5) cold temperate zone.

Although the Northeast Asia sub-region contains only one-twelfth of the world's total land resources, it contains about one-fourth of the total global population. The per capita land resources of the sub-region is only 0.0078.km^{-2} (0.003.mi^{-2}), accounting for one-third of the world average. The total arable land area of the sub-region is 1,390,046 km^{2} (536,700 mi^{2}), accounting for about 11.82 per cent of the region's total land area, while forests cover 2,305,080 km^{2} (889,996 mi^{2}; 19.59 per cent); grasslands 4,285,510 km^{2} (1,654,645 mi^{2}; 36.42 per cent); and other lands 2,732,876 km^{2} (1,055,169 mi^{2}; 23.23 per cent). Generally speaking, the sub-region generally has an inadequate area of arable land for sustained agricultural productivity.

The Northeast Asia sub-region is rich in biological resources, with a complicated distribution pattern, and one of the regions of the world with the richest plant and animal resources. About 170 identified mineral species have been report for the region. It has a rich resource base, including tungsten, antimony, thulium, molybdenum, vanadium, and titanium. It also is rich in coal, iron, lead, zinc, copper, silver, mercury, tin, nickel, phosphorus, asbestos, graphite, and magnetite.

The sub-region has a total population of 1,508,263,000. The population density is about 128.km^{-2} (332.mi^{-2}) one of the most densely populated areas in the world. According to the statistics over the past 5 years, the natural population growth rate is 9.36 per cent, thereby exhibiting a decreasing trend, compared to the figures in the 1980s and 1990s. At the same time, the number of the aged population is increasing in the sub-region.

The GDP growth rate of the Northeast Asia sub-region in 2006 was 9.275 per cent (excluding D.P.R. Korea), which is about 1.5 times higher than the predicted rate. The total GDP is US$ 7,635 billion, and US$5,062.capita^{-1}, accounting for 62 per cent of the world's average per capita GDP. This demonstrates the sub-region is in a fast period of growth period, although it still has far to go to reach the average global level, with the difference between developed and developing countries still being large.

Freshwater Resources

The freshwater resources of the Northeast Asia sub-region, which exhibits a complex influence of geographic and topographic features and climate, are characterized as: (1) rivers flowing over long distances; (2) large river basins; (3) many water falls; (4) high density of international rivers; and (5) large differences among the riparian countries.

The total available water resources of the sub-region (excluding D.P.R. Korea, which has no available data) is 3,351 km^3, accounting for about 1/300th of the global total. The per capita water availability is 2,221 m^3, only about 25.7 per cent of the world's average. Thus, the sub-region is water scarce, in terms of both total and per capita water resources.

The sub-region is relatively rich in precipitation, with an annual precipitation of about 1,100 mm (43 in), with an obvious gradient distribution, decreasing from the east to the west, and from the south to the north. According to the iso-precipitation lines, about 54 per cent of the area in this sub-region is in the humid and semi-humid category, while the other 46 per cent is in semi-arid and arid zones. There are frequent monsoons during the rainy season, with about 70-80 per cent of the annual precipitation occurring in the monsoon season. The water supply in the dry season normally comes from groundwater aquifers, stored water, and melting snow. The frequency of floods and droughts (about every 50 years) has increased over the last 200 years. The trend of drought occurrence is even more obvious, having increased by 36 per cent over the same period. These observations illustrate an increased vulnerability of water resources in the region.

Excluding D.P.R. Korea, the total water use in the Northeast Asia sub-region is 684.3 km^3, accounting for 29.7 per cent of the global total. The per capita water use is 454 $m^3.year^{-1}$, about 1.2 times the global average. Up to 2002, about 335,000,000 inhabitants lacked adequate access to safe drinking water. Compared to the situation in 1990, however, the safe drinking water supply has improved rapidly in recent years, resulting from implementation of the Millennium Development Goals (MDGs), which targeted that half of the world's population without access to improved drinking water will be halved by 2015.

As a consequence of expanded land reclamation and over-irrigation, lake ecosystems in the sub-region have experienced heavy pressures over the past decade, and the total water surface area has decreased. Water quality deterioration is another crucial problem in this sub-region.

For a region with scarce water resources, one of the crucial needed measures for balancing water supply and demands is to increase water use efficiency. In turn, water use efficiency is a function of several variables, including technology, price and state of knowledge.

As an important indicator, the water use per unit GDP (WUGDP) reflects governmental achievements in water savings and environment protection.

Up to 2002, the Northeast Asia sub-region had about 751,000,000 people lacking access to improved sanitation, with 78.3 per cent being in rural areas. Nevertheless, more people in the sub-region have access to improved sanitation today, compared to the 1990s.

The complex physical, political, and human interactions within international river basins in the sub-region can make management of the shared water systems especially problematic. To prevent potential conflicts and resolve existing disputes, the international community has focused considerable attention in the 20th century on developing and refining principles of international freshwater management.

Vulnerability Assessment

Based on the general description of the water resources base in the Northeast Asia sub-region, a systematic analysis on vulnerability of freshwater resources was implemented for the sub-region. Based on the joint efforts of Chinese team and Mongolian team, 5 major river basins were identified for detailed analysis: The Changjiang River Basin (CRB), Huanghe River Basin (HRB) and Songliao Basin (SLB) in China, and the Orkhon River Basin (ORB) and Tuul River Basin (TRB) in Mongolia. The key factors related to freshwater vulnerability were summarized.

Water Resources and Climate Change

The sub-region, although relatively rich in precipitation, is characterized by a vulnerable water resources base. On the one hand, most of the river basins are located in the continental climate zone, where precipitation is low (i.e., arid and semi-arid zone). On the other hand, the temporal distribution and variability of precipitation, attributed to climate change tends to be a fundamental factor contributing to the increasing vulnerability of the freshwater resources. In the semi-humid, semi-arid and arid zones, declining precipitation and runoff trends were observed, with the speed of change now accelerating. As a result, water is becoming an increasingly scarce resource, with some rivers even partially dried out. There also is an increasing precipitation and runoff trend in the humid zone, particularly over the last 10 years. The influence of the monsoon can be observed in the precipitation characteristics, with about 70-80 per cent of the precipitation occurring during June to September. Thus, floods in the rainy season have become a major problem in these areas.

Agricultural Water Use and Drinking Water

Most of the irrigation in the sub-region is still “extensive”, with irrigation efficiency being low (as low as 25 per cent). Thus, agricultural irrigation is a sector that exhibits both a large water consumption and large water wastage. Due to limited water quantity and poor water quality, a huge proportion of the population in the sub-region lacks access to improved drinking water supply (IDWS).

Ecosystem Deterioration

In addition to shrinking lakes and wetlands, the habitats of vegetation and animals are gradually being lost, resulting in biodiversity loss in the sub-region. Statistically, many endemic and endangered species (fish, amphibian, waterfowl, and aquatic mammals) are threatened with extinction.

Water Pollution

The water quality has generally deteriorated throughout the Northeast Asia sub-region. Water pollution pressures result from the following activities: (1) increasing population; (2) rapid economic development; (3) improper industry structure; and (4) decreasing investments in wastewater and sewage disposal equipment. Water pollution changes the water scarcity situation from bad to worse, severely affecting agricultural, industrial and domestic water supplies, and harming the health of humans and aquatic biodiversity. In urban areas, pollution pressures increase the potential for high sewage emissions from centralized water systems, and a wastewater treatment efficiency. Further, water pollution aggravates economic losses, while restricting sustainable circulation among economy, society, and ecological environment. It is clear that governments in the sub-region must make an all-out effort to improve overall water quality.

Water Use Efficiency

Generally speaking, the WUGDP as an important indicator of water use efficiency, reflecting the achievements of governments in water savings and environment protection. Because of a lack of an appropriate valuation mechanism at policy level, however, water resource use cannot be effectively controlled under the current policy framework. As a result, the price of water resources could not be appropriately established, and is usually badly under-estimated, with the issue of water scarcity and water pollution getting more aggravated. About 70 per cent of the water is being lost during its transportation and distribution. Thus, with increased investments in water-saving facilities and water use management, water use efficiency should improve.

Vulnerability Index

Based on an in-depth assessment, a Vulnerability Index (VI) was calculated for each of the 5 selected river basins, with the results summarized in the following table.

Vulnerability Index for 5 selected river basins in Northeast Asia sub–region

	RSs	RSv	DPs	DPd	EHp	EHe	MCe	MCs	MCc	VI
CRB	0.000	0.225	0.195	0.145	0.174	0.395	0.929	0.145	0.400	0.264
	0.113		0.169		0.286		0.491			
SLB	0.128	0.740	0.330	0.182	0.231	0.370	0.937	0.229	0.290	0.369
	0.434		0.256		0.300		0.486			
HRB	0.684	0.347	0.656	0.250	0.680	0.520	0.995	0.250	0.400	0.529
	0.516		0.453		0.600		0.548			
TRB	0.255	0.554	0.041	0.379	0.420	0.829	0.657	0.574	0.340	0.441
	0.405		0.210		0.625		0.524			
ORB	0.000	0.515	0.022	0.827	0.073	0.073	0.956	0.952	0.420	0.383
	0.257		0.428		0.073		0.776			

Low	Moderate	High	Severe

The following conclusions are based on this analysis:

[1] The vulnerability grades of the 5 selected river basins generally range from moderate to high, and management-related interventions are urgently needed to improve the state of water resources in the sub-region.

[2] Except for the CRB (located in humid and semi-humid zone) and the ORB (with very low population density), the remaining river basins in the sub-region generally exhibit water resources problems. Their basins are relatively dry, and exhibit a low per capita availability of water resources. In addition to water scarcity, they also suffer from unstable annual water resources recharge capacity. As an example, the SLB experiences serious water shortages related to large inter-annual variability in precipitation that increase the constraints to adopting sustainable water resources management plans practices.

[3] In regard to water resources development and use, the water resources exploitation rate is usually high in the river basins suffering from water shortages. This is clearly demonstrated with the HRB analysis, which identified a water resources exploitation rate as high as 65 per cent. Further, although the other river basins don't exhibit a critical designation, the continuous population increase and urban expansion occurring in them require a continually-increasing

water supply, thereby also presenting future water resources development and use challenges. Further, over-exploitation of both surface and groundwater resources will negatively impact the healthy hydrological processes, subjecting the river basin to high ecological risks.

[4] In terms of ecological health, most of the river basins are at risk, including those currently exhibiting a low vulnerability, mainly because of the continuous deterioration of water quality in the sub-region, and the increasing recognized problematic development trends, based on the available data. This conclusion also is supported by another indicator; namely, vegetation coverage (including wetland). The vegetation coverage is relatively low in all 5 selected river basins, further contributing to increased limitations in regard to eco-rehabilitation.

[5] There is a high disparity in management capacity among the 5 selected river basins, with the common problem being poor water use efficiency. Although most of the river basins exhibit a scarce water supply, due to various factors affecting management capacity (both technical and policy in nature), water use efficiency remains very low.

[6] Conflict management is another important indicator for the countries in the Northeast Asia sub-region with transboundary river basins. Although they are not all international rivers, the 5 selected river basins are large in area, and exhibit various levels of transboundary management issues. The management of the 3 selected river basins in China, for example, is similar in regard to institutional arrangements, but still exhibit minor variations in terms of management capacity. The situation is similar for the 2 selected Mongolian river basins.

Policy Recommendations

Based on the above synthesis, the following policy recommendations should be considered for improving water resources management in the future:

[1] Improved water use efficiency – Although the 5 selected river basins are located mostly in arid and semi-arid zones, and characterized by scarce water resources, the water use efficiency remains very low. The key factors contributing to water use efficiency are development policy and technical input. Water use is still dominated by the agricultural sector in the Northeast Asia sub-region, with water use efficiency in agricultural sector being relatively low, compared to other sectors. Thus, the development policy in the agricultural sector must be re-assessed, and relevant policies formulated to improve water use efficiency in this sector, including: (1) refinements in the structure of agricultural production; and (2) introduction of economical incentives in water-pricing policies. Improved water use efficiency also will require strong technical support (e.g., development of water-saving technologies in agriculture and other industries). The research and development (R&D) activities for water resources management in the Northeast Asia sub-region are relatively low, and should be included in the priorities of the technological development agenda of the countries of the sub-region.

[2] Comprehensive river basin management – The current water resources management scheme is based on a political administrative system that is weak in regard to enhancing coordination between different reaches of the various river basins. Different reaches of the river basins have unique characteristics, and play different roles in the whole river basin ecosystems. The current centralized management system leaves little opportunity for cross-basin coordination. Thus, basin-wide management institutions must be further strengthened through decentralization and proactive involvement of local governments. At the same time, the participation of all water stakeholders, as a key to successful river basin management, also must be encouraged. Another important aspect of basin-wide management is ensuring rational water resources use through a coordinated mechanism for water resources allocations.

[3] Environmental protection and pollution control – Except for the ORB, which exhibits a better ecological condition in regard to both pollution and vegetation, the remaining 4 river basins analysed in this study are under severe threats of environmental degradation. Thus, protecting the environment will be very important for restoring the degraded ecosystems. Relevant measures may include erosion and sedimentation control, sufficient ecological flows, and pollution control through controlled pollutant discharges.

[4] Poverty alleviation and safe drinking water – Poverty alleviation will remain an important development task of integrated river basin management for a long time. Management priorities must be established to meet the basic needs of the poor population, including safe drinking water supply, establishment of alternative livelihoods, and building the capacity of local people to solve their problems through participatory resources management activities.

1 Introduction

1.1 Rationale

Water resources are normally considered to be the total quantity of freshwater readily available for human use. Although the total quantity of water on earth is enormous (about 1.338 $\times 10^9$ km^3), the freshwater readily available for human use is only a very small portion of this total quantity (only about 2.53 per cent). And 70 per cent of this readily-available freshwater exists in the form of glaciers or permanent snow, under permanently-frozen soil, or deep underground beyond easy human access. About only 1.065$\times 10^7$ km^3 of the earth's freshwater resources are available as surface water, or as groundwater that is less than 600 m (1,968 ft) under the land surface, thereby being easily accessible for human use. In fact, our readily-available freshwater resources consist of only about 30.4 per cent of the total freshwater resources, and only about 0.77 per cent of all the water on earth.

As a result of continuing population growth and evolution of human society, human demands for water resources continue to increase. At the same time, expanding human activities have negatively influenced the health of the earth's freshwater systems, thereby contributing to the vulnerabilities of our planet's water systems. It is reported that, among the 500 great rivers of the world, more than half are drying (UNEP 2002B). Because of these water-related threats, the biodiversity of freshwater ecosystems is decreasing rapidly, and at a rate even faster than that of terrestrial and marine ecosystems.

According to United Nation reports, human water use has increased by a factor of 6 over the 20th century. In addition to the impacts related to uneven spatial and temporal distribution, mismanagement, insufficient infrastructure, and environmental pollution, our limited freshwater resources have resulted in approximately one-fifth of the world's population lacking access to safe drinking water, as well as inadequate sanitation facilities for approximately 40 per cent of the world's population (ADB, 2006).

Wise water resources management, therefore, is one of humanity's major challenges in its quest toward sustainable development. Equally challenging is inclusion of water resources management, as an important component of ecosystem management, in the development agenda of many of the world's countries. Thus, formulation of an effective policy for implementing integrated water resources management requires a comprehensive knowledge base, with an increased understanding of the vulnerability of water resources being a key goal for this purpose.Therefore, an initiative directed to understanding the vulnerability of freshwater resources within the context of climatic and socioeconomic changes will definitely contribute needed information for better decision-making directed to the water sector. To this end, this study is a joint effort between different agencies and institutions around the world, directed to better awareness building and decision support, with this report on the vulnerability status of the Northeast Asia sub-region being part of this global initiative.

1.2 Approach

1.2.1 General Analytic Framework

The vulnerability assessment of freshwater resources in Northeast Asia sub-region was carried out in a two-step process: (1) in-depth assessments of the selected river basins; and (2) synthesis of results for the entire sub-region, based on the assessments of the selected river basins. The distinguishing feature of this exercise is an integrated river basin analysis approach. With this systematic method, river basins are used as the basic unit of assessment, with all the scientific data collected at the river basin scale, within which the hydrological and socioeconomic processes are closely linked. The dynamics of a river basin, including both the hydrological and socioeconomic processes, can effectively demonstrate the state and trends regarding the basin's water resources. Thus, the results of these analyses should reflect a dual adaptation process; namely, ecological and socioeconomic adaptations.

The vulnerability assessments of freshwater resources of the selected river basins in this study were carried out under the general guidelines of *Methodological Guidelines for Vulnerability Assessment of Freshwater Resources*, developed in this project. This method is a results-oriented assessment aimed at enhancing our understanding of water resources of a river basin as the fundamental analysis framework, and its interrelationships with the social adaptations of the local socioeconomic system. As shown in Figure 1.1, the analytic framework has four basic components: (1) water resources base; (2) water resources development and use; (3) water resources for ecological health; and (4) water resources management. The first three components are important components of the hydrological process, with the state and trends usually being ideal indicators of the vulnerability of water resources, while the management component can influence each of the first three components, reflecting the socioeconomic adaptations in a complex water resources system.

The conceptual framework of analysis is based on the assumption that a healthy water resources management system can best be realized with the establishment of a rational, coordinated relationship between the three above-noted components through appropriate management schemes. Thus, the vulnerability assessment of a river basin requires a precise understanding of the four components, including its state, trends and the relationships with its context, as follows:

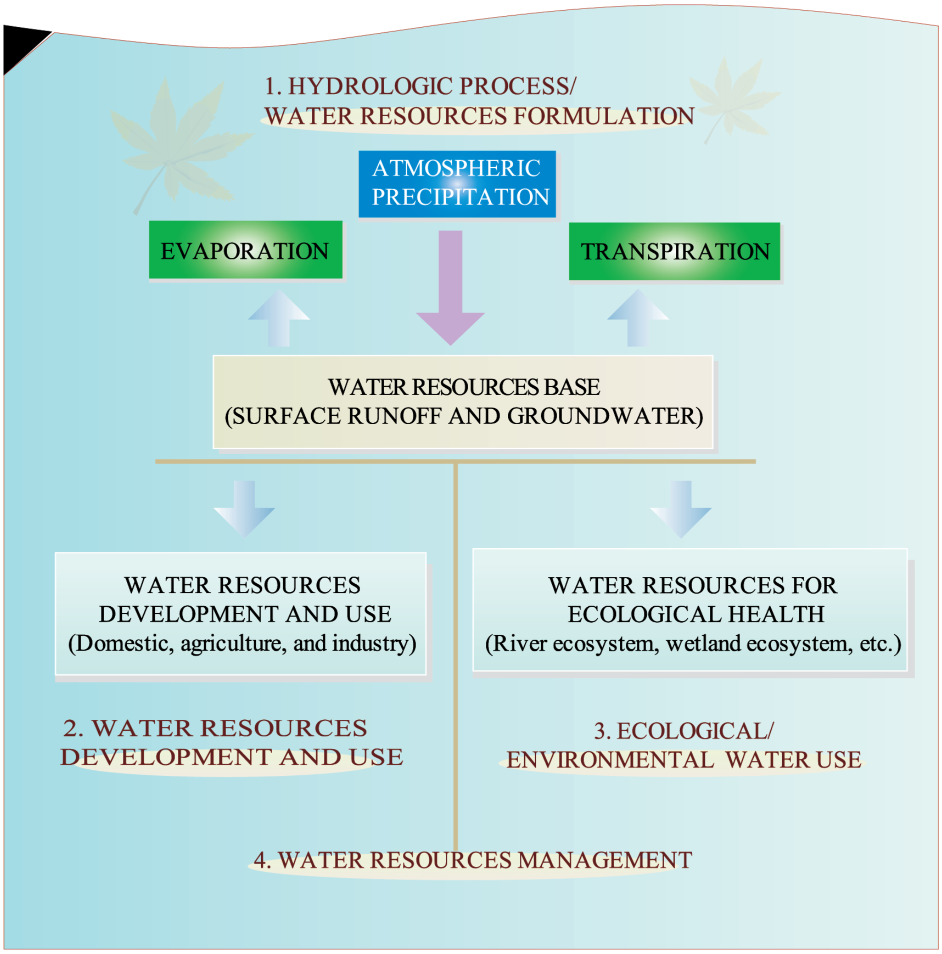

Fig. 1.1 A Simplified framework of water resources base, and its development and use in a river basin

[1] Water resources base – Analysis of the hydrologic balance prior to consideration of any water resources development and use; that is, water resources formulation from a natural hydrologic process, and its relationship with global climate change and local biophysical conditions.

[2] Water resources development and use – Analysis of the balance between water resources supplies and needs; that is, the water resources development capacity utilizing an engineering approach, and its relation to water resources use, including domestic water development trends (e.g., urbanization, modernization), as well as the roles and support provided by water resources to economic development.

[3] Water resources for ecological health – Analysis of water resources subsequent to its development and use for domestic and economic use; for maintaining the basin's ecological health; supply and demand relations; and key issues in the process. At the same time, water quality must be analysed as a consequence of water resources development and use (pollution),

and its influences on water resources budgeting within a river basin.

[4] Water resources management – The above three components focused on natural processes, or natural adaptations, of freshwater resources development and use. At the same time, the natural process is usually heavily influenced by the social adaptation capacity to freshwater resources (i.e., the freshwater resources management capacity plays an important role in establishing and maintaining a healthy freshwater resources development and use system). Thus, the vulnerability assessment should also consider the capacity of the management structure to evaluate the state and trends of institutional arrangements, transboundary coordination, and other relevant factors in freshwater resources management.

Based on this framework, the assessments comprised 3 steps:

[1] Diagnosis of key issues in each of the four components – To demonstrate the state and development path through a comprehensive analysis of the hydrological database; demonstrate the state and developmental path of each component in the framework; and identify key issues for each component relevant to the goal of sustainable water resources management practices;

[2] Detailed analysis of the identified issues, using the Driver-Pressure-State-Impact-Response (DPSIR) framework – For all the issues identified in the first step, the DPSIR approach is used for in-depth technical assessments for understanding the causality relationships among the drivers, pressures, state, impacts and responses that provide precise technical guidance for policy recommendations; and

[3] Comprehensive assessments supported by calculation of the VI – The comprehensive assessments are carried with an integrated Vulnerability Index system (VIS). The purpose of the VIS is to try to provide a generally-understandable indicator matrix for describing the vulnerability state of a river basin, and to make the results comparable across different river basins.

The VIS is composed of a series of indicators structured in a two-stratum fashion. At the first stratum, there are four variables representing the four key components of the analytical framework, including resources stresses; development pressures; ecological health; and management challenges. Thus, the vulnerability of a river basin can be expressed as:

$$VI = f\,(RS, DP, EH, MC)$$

where: VI = Vulnerability Index; RS = Resource Stresses; DP = Development Pressures;

EH = Ecological Health; and MC = Management Capacity

The second stratum of the VIS is a set of computable parameters for each of these four variables. Table 1.1 identifies all the parameters in a two-stratum structure of the VIS.

Table 1.1 Indicator structure of Vulnerability Index System for freshwater resources assessment

First stratum	Second stratum	Symbol	Definition	Calculation
Resource stresses (RS)	Water scarcity	RSs	Per capita water resource of a region, compared to generally-agreed minimum level of 1,700 $m^3.person^{-1}$	$RS_S = \frac{1700-R}{1700}$ $(R \le 1700)$; $RS_S = 0$ $(R > 1700)$
	Water variation	RSv	Coefficient of variation of precipitation over the last 50 years.	$RS_v = \frac{CV}{0.3}$ $(CV < 0.3)$; $RS_v = 1$ $(CV \ge 0.3)$
Development pressures (DP)	Water stress	DPs	Per cent of water supply, relative to total water resources	$DP_S = \frac{WR_S}{WR}$
	Safe drinking water accessibility	DPd	Per cent of population without access to safe drinking water	$DP_d = \frac{P_d}{P}$
Ecological health (EH)	Water pollution	EHp	Proportion of discharged wastewater, relative to total water resources	$EH_p = \frac{WW/WR}{0.10}$ $(WW < 0.10 \times WR)$; $EH_p = 1$ $(WW \ge 0.10 \times WR)$
	Ecosystem deterioration	EHe	Per cent of exposed land area (without vegetation)	$EH_e = \frac{A_d}{A}$
Management capacity (MC)	Water use efficiency	MCe	Level of water use efficiency (GDP from unit water consumed)	$MC_e = \frac{WE_{wm} - WE}{WR_{wm}}$ $(WE < WE_{wm})$; $MC_e = 0$ $(WE \ge WE_{wm})$
	Improved sanitation accessibility	MCs	Per cent of population without access to improved sanitation	$MC_S = \frac{P_S}{P}$
	Conflict management capacity	MCc	Capacity in conflict management for transboundary issues	Consultation

The detailed calculation methods are discussed in the Methodological Guidelines, with the interpretation of results being based on the interpretation criteria identified in Table 1.2.

Table 1.2 Reference sheet for interpretation of Vulnerability Index

Vulnerability Index	Interpretation
Low (0.0 – 0.2)	This is a healthy drainage basin, in terms of resource richness, development practices, ecological state, and management capacity. No serious policy change is needed. It is still possible, however, that moderate problems exist in one or two aspects of the assessed components for the basin, and policy adjustment should be considered after examining the VI structure.
Moderate (0.2 – 0.4)	This river basin is generally in a good condition in regard to achieving sustainable water resources management. It may still fact challenges, however, in regard to either technical support or management capacity building. Thus, policy design for the basin should focus on the main challenges identified after examining the VI structure, and strong policy interventions should be designed to overcome any key constraints to the river basin.
High (0.4 – 0.7)	The river basin is under high stress, and great efforts should be undertaken to design policy that provides technical support and policy backup to mitigate these stresses. A longer-term strategic development plan should be developed, with a focus on rebuilding management capacity to deal with the main threats.
Severe (0.7 – 1.0)	The river basin is highly degraded in regard to its water resources system and management structure. Restoration of the river basin's water resources management capabilities will need high commitments from both the government and the general public. Its restoration will be a long-term process, and an integrated management plan must be developed at the basin level, with the involvement of appropriate international, national and local level agencies.

Upon completion of assessments of the selected river basins, a sub-regional synthesis will be made, utilizing a similar framework as that used for the river basin assessment. The synthesis report for the sub-region includes two inter-related sections: (1) A general introduction and analysis of the vulnerability of sub-regional water resources in a similar manner as the river basin assessment; and a subsequent (2) more in-depth technical assessment of the key characteristics and issues, based on the results from the selected river basin assessments. The summary of the sub-region assessment is to provide comprehensive comments and policy options, based on the key messages from the first two sections, and a calculation and mapping of the vulnerability indicators for the selected river basins.

1.2.2 The Process

Based on the general analytic framework, the assessment of the Northeast Asia sub-region was divided into three phases, as follows:

[1] Assessments of the selected river basins – Five river basins were selected for in-depth analysis, 3 in China, and 2 in Mongolia, as follows: (1) Changjiang River Basin (China); (2) Huanghe River Basin (China); (3) Song-Liao Basin (China); (4) Orkhon River Basin (Mongolia); and (5) Tuul River Basin. Two research teams were formed in China and Mongolia to carry out assessments of the selected river basins. Upon completion of a desk study, the two teams met in a joint workshop to discuss the methodological issues for the assessments, including data analysis; calculation of the VI; etc. Upon completion of the first draft of the assessment reports for each of the individual river basin, draft reports were sent to local experts for review and comments, which were used to further improve the reports.

[2] Synthesis report for the sub-region – The synthesis report was prepared on the basis of the reports for the selected river basins. The sub-region teams conducted a more descriptive analysis of the freshwater resources status and trends for the selected river basins in a framework similar to that utilized for the individual river basin. Based on the general descriptive analysis, detailed analyses on the key issues of the sub-region were conducted, using the DPSIR framework based on the results from the river basin assessments. The final recommendations and policy options were based on an in-depth analysis of the VI indicators' mapping. Similar to the river basin reports, the draft synthesis report was sent to experts for comments, being further revised on the basis of these comments.

[3] Review workshop – A review workshop was organized for the sub-region, with the river basin reports and the sub-regional synthesis report being reviewed by an expert panel from the sub-region. The reports were finalized on the basis of the comments received from the expert panel.

1.3 Structure of Report

This report includes three sections, as follows: (1) a general introduction to the sub-region, and the main factors affecting freshwater resources in all countries of the sub-region; (2) in-depth synthesis of vulnerability assessment of freshwater resources, based on the results from the 5 selected river basin assessment case studies; and (3) full reports of the 5 case studies, provided as an appendix to this report.

2 Overview of Freshwater Resources in Northeast Asia Sub–region

2.1 Overview of Sub–region

The Northeast Asia sub-region covers a vast area of 11,764,596 km^2 (5,314,540 mi^2), accounting for about 1/12th of the total land area in the world. It borders the Pacific Ocean, with a total coastal line of 86,199 km (53,562 mi), and has more than 22,000 islands (MFA of PRC; Xinhuanet; GOVCN-A; CYS, 2006; MSY, 2005). The sub-region (Figure 2.1) is composed of 5 countries: People's Republic of China (P.R. China), Mongolia, Japan, Republic of Korea (R. Korea), and Democratic Peoples Republic of Korea (D.P.R. Korea).

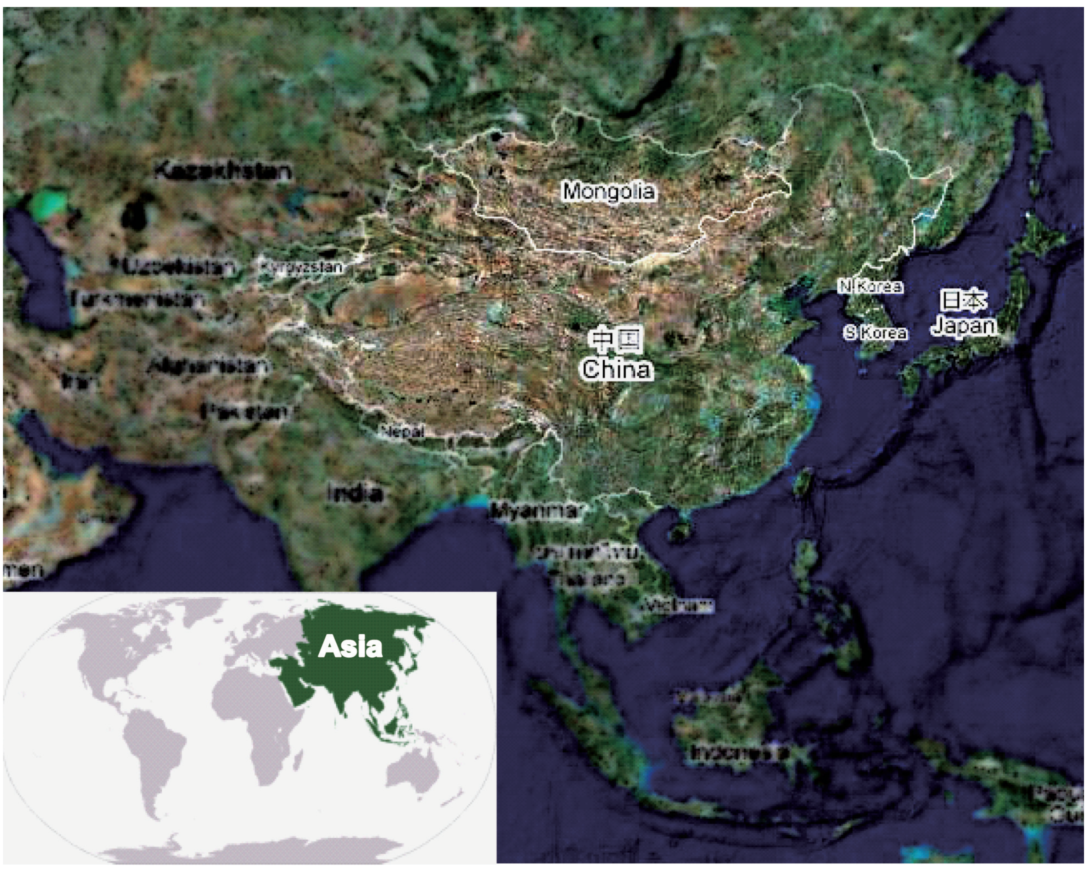

Fig. 2. 1 Northeast Asia sub–region (Google Earth)

2.1.1 Topography

The Northeast Asia sub-region exhibits diverse topographic features (Table 2.1), including 5 basic topographic types (plateaus; plains; basins; mountains; hills). With mountains as its main topographic type (accounting for 54.6 per cent of the land area), the sub-region is generally characterized by steep slopes and rugged landform. Thus, it provides the sub-region with many tall vertical falls, suitable for potential hydropower development. As an example, China has a potential hydropower capacity of 680,000,000 kw (CSY, 2006).

Table 2.1 Distribution of landform types in Northeast Asia sub−region

Landform	P.R.China	Mongolia	Japan	R. Korea	D.P.R. Korea
Plateau	Northwest and southwest	North	—	Northeast and northwest	Northeast
Plain	East	East	Northeast, middle and southwest	South and west	South
Basin	Northwest and middle	Southeast	—	—	—
Mountain	Middle	West, north and middle	Northeast, middle and southwest	East and north	East, south and north
Hill	Southeast and southwest	Southeast	—	South and west	—

There are 3 topographic steps from the west to the east, and the height gradually decreasing. The highest step in the west is the Qinghai-Tibetan Plateau. With an average altitude over 4,000 m (13,124 ft), it is composed of well-distributed mountain ranges and deep valleys, and several snow mountains stretch across the plateau. This plateau is the source of the two major rivers, the Changjiang and Huanghe Rivers. The second step is composed of vast highlands and basins, with a average altitude ranging from 1,000 to 2,000 m (3,280 to 6,560 ft), including the Mongolian Plateau, Inner Mongolian Plateau, Loess Plateau, Yunnan-Guizhou Plateau, Yeongseo Plateau, Jinan Plateau, Junggar Basin, Tarim Basin, Caidam Basin and Sichuan Basin. The third step includes alternatively-distributed hilly regions (about 1,000 m [3,280 ft] in altitude) and plains (below 200 m [656 ft] in altitude); namely, the Northeast China Plain, North China Plain, plains in the middle and lower reaches of the Changjiang River Basin, Zhujiang River Delta Plain, Kanto Plain, Ishikari Plain, Niigata Plain, Osaka Plain, etc. The third step also extends to the Pacific Ocean, and links to the continental shelf.

2.1.2 Climate

Because of its vast land area, the Northeast Asia sub-region exhibits a widespread coverage across the latitude, large variations in distances to the sea, and diverse topographic types. It exhibits a rich combination of temperature-precipitation patterns, which typically include continental climate, Oceania climate, and monsoon climate (Table 2.2), as follows:

Table 2.2 Distribution of climate types in Northeast Asia sub−region

Climate type	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Continental	√	√			
Oceanic			√	√	√
Monsoon	√		√	√	√

[1] Continental climate – This portion of the sub-region has very cold winters and hot summers, with the annual temperature variation being high. The precipitation is normally concentrated in the summer (Table 2.3). The typical areas exhibiting this temperature-precipitation pattern are Mongolia, and the northwest and north parts of China.

[2] Oceania climate – This portion exhibits a small annual temperature variation, remaining warm and humid throughout the year (Table 2.3). The typical areas exhibiting this temperature-precipitation pattern are Japan, R. Korea, and D.P.R. Korea.

[3] Monsoon climate – This portion experiences prevailing warm and humid south winds from the Pacific Ocean or Indian Ocean during the summer, with the prevailing winds changing to dry and cold north winds from the continents in the winter. Under the influence of the prevailing winds, more rainfall occurs in the summer and less in the winter, with an obvious seasonal change throughout the year. The typical areas exhibiting this temperature-precipitation pattern are the east and south parts of China, Japan, R. Korea, and D.P.R. Korea.

Table 2.3 Temperature characteristics of Northeast Asia sub−region (MFA of PRC; Xinhuanet; CYS, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Multi-year mean temperature (℃)	4～23	0.25	10～15	11～16	8～12
Summer mean temperature (℃)	31	17.5	28	27	27
Winter mean temperature (℃)	−17	−20.2	−6	−8	−10

The Northeast Asia sub-region can be divided into 5 temperature zones, based on the annual accumulated temperature (with daily mean temperature higher than 10 °C [50 °F]). These include a tropical zone, sub-tropical zone, warm temperate zone, middle temperate zone, and cold temperate zone (Table 2.4). In addition, the Qinghai-Tibetan Plateau's temperature zone cannot be described with the above-mentioned temperature zones because of its special topographical features, thereby being treated as a special zone.

Table 2.4 Distribution of temperature zones in Northeast Asia sub−region (GOVCN−B, MFA of PRC; CSY, 2006)

		Tropical	Sub-tropical	Warm temperate	Middle temperate	Cold temperate
Accumulated temperature (℃)		> 8,000	4,500 ~ 8,000	3,400 ~ 4,500	1,600 ~ 3,400	< 1,600
Crop growth period (Day)		365	218 ~ 365	171 ~ 218	100 ~ 171	< 100
Distribution range	P.R. China	1.HNP[1] 2.South of YNP[2], GDP[3], TWP[4]	1.South of QLM5-HHR[6] 2.East of QTP[7]	1.Most of middle & lower reach of HRB[8] 2.South of XJUAR[9]	1.South of HLJP[10] 2.JLP[11].LNP[12] 3.Most of IMAR[13] 4.North of XJUAR	1.North of H.L.J.P. 2.Northeast of I.M.P
	Mongolia	—	—	—	1.East 2.West 3.South	1.North 2.Northeast
	Japan	—	South of Kyushu	1.North of Kyushu 2.Honshu Shikoku	South of Hokkaido	North of Hokkaido
	R. Korea	—	—	All	—	—
	D.P.R. Korea	—	—	All	—	—

Explanation:

1. HNP = Hainan Province; 2. YNP = Yunnan Province; 3. GDP = Guangdong Province; 4. TWP = Taiwan Province; 5. QLM = Qinling Mountains; 6. HHR = Huaihe River; 7. QTP = Qinghai-Tibet Plateau; 8. HRB = Huanghe River Basin; 9. XJUAR = Xinjiang Uygur Autonomous Region; 10. HLJP = Heilongjiang Province; 11. JLP = Jilin Province; 12. LNP = Liaoning Province; 13. IMAR = Inner Mongolia Autonomous Region

2.1.3 Nature Resources

2.1.3.1 Land Resources and Land Use

The Northeast Asia sub-region has only one-twelfth of the world's total land resources, but contains one-fourth of the total global population. The per capita land resources of the sub-region is only 0.0078.km^{-2} (0.003.mi^{-2}), accounting for one-third of the world's average (MFA of PRC; Xinhuanet; CSY 2006; MSY, 2005). Thus, the sub-region has very limited land resources to support its large population. Further, the per capita land resources also vary from country to country within the sub-region. Except for Mongolia, which has a relatively high per capita land resource, the remaining 4 countries have very low per capita land resources. As illustrated in Table 2.5, Japan has the lowest per capita land resources, equivalent to only 0.5 per cent of that of Mongolia.

Table 2.5 Land resources in Northeast Asia sub−region (MFA of PRC; Xinhuanet, CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Land area (km^2)	9,600,000	1,564,116	377,880	99,600	123,000
Per capita land area (km^2.$capita^{-1}$)	0.0073	0.6110	0.0030	0.0021	0.0053

Based on the topographic, landform, climatic and other natural conditions, diverse types of land use systems provide favourable conditions for development of agriculture, forestry, stock breeding, fishery and other land use-based industries exist in the Northeast Asia sub-region. There also are large proportions of land, however, that cannot be exploited for any economic activities. As an example, about 12 per cent of the territory of China is desert (Gobi), which is ecologically fragile and has low land use development value (GOVCN-C). As shown in Table 2.6, the total arable land in the Northeast Asia sub-region is 1,390,046 km^2 (537,000 mi^2), accounting for only about 11.82 per cent of the total land area, forests cover 2,305,080 km^2 (889,996 mi^2; 19.59 per cent), grasslands cover 4,285,510 km^2 (1,654,645 mi^2; 36.42 per cent), and other types of land occupy 2,732,876 km^2 (1,055,069 mi^2; 23.23 per cent). As a general observation, the sub-region suffers from a serious lack of arable land. The per capita arable land is only 0.00122 km^2.$capita^{-1}$ (0.0032 mi^2.$capita^{-1}$; Table 2.6), much lower than the world average of 0.0367 km^2.$capita^{-1}$ (0.095 mi^2.$capita^{-1}$), and even lower than the safe level (0.0053 km^2.$capita^{-1}$ [0.0137 mi^2.$capita^{-1}$]) of arable land by the FAO.

Table 2.6 Distribution of land use types in Northeast Asia sub−region (MFA of PRC; Xinhuanet; CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Arable land area (km^2)	1,300,392	1,758	49,896	19,500	18,500
Ratio of arable land area (per cent)	13.54	0.11	13.20	19.58	15.04
Per capita arable land area ($km^2.capita^{-1}$)	0.00099	0.00069	0.00039	0.00041	0.00080
Forestry land area (km^2)	1,749,100	147,480	251,500	64,000	93,000
Ratio of forestry land area (per cent)	18.22	9.43	66.56	64.26	75.61
Pasture land area (km^2)	3,133,300	1,152,210	—	—	—
Ratio of pasture land area (per cent)	32.64	73.67	—	—	—
Inland water area (km^2)	174,700	9,676	—	—	—
Ratio of inland water area (per cent)	1.82	0.62	—	—	—
Other land area (km^2)	2,375,800	252,992	76,484	16,100	11,500
Ratio of other land area (per cent)	24.75	16.17	20.24	16.16	9.35

2.1.3.2 Biological Resources

The Northeast Asia sub-region is rich in biological resources, with one of the richest plant and animal resources, and which exhibit complicated distribution pattern. In the east, the monsoon area contains diverse vegetation communities, including tropical rain forests, seasonal tropical rain forests, central and south sub-tropical evergreen broadleaved forests, north sub-tropical deciduous and evergreen broad-leaved mixed forests, temperate deciduous broad-leaved forests, cold temperate conifer forests, sub-alpine conifer forests, temperate forest meadow, and so on. The northwestern part of the sub-region (Qinghai-Tibetan Plateau) contains steppes, semi-desert primary shrub lands, dry desert shrub lands, dry desert grasslands and shrub lands, plateau cold desert, and highland grassland and meadow. The sub-region also has diverse biological species. It is reported, for example, that China has more than 24,600 species of higher plants, belonging to 2,980 genera of 300 families. These organisms include: (1) 2,946 genera of angiosperms (23.6 per cent of the global total angiosperms); (2) large numbers of genera of ancient species (62 per cent of the world's total); (3) large number of economic plants, including over 1,000 timber species, over 4,000 medicinal species, more than 300 fruit and nut species, more than 500 fibre species, 300 starch species, 600 oil species, and more than 80 vegetable species. China also contains 2,070 terrestrial vertebrate animals species, accounting for 9.8 per cent of the world's total, including 1,170 bird specie, 400 beast species, and 184 amphibious species (accounting for 13.5, 11.3 and 7.3 per cent, respectively, of the world's total) (GOVCN-D).

2.1.3.3 Mineral Resources

The Northeast Asia sub-region is a vast territory with a complicated geological structure, also being rich in mineral resources. The sub-region contains an estimated 170 identified mineral species. It has the world's richest resources of tungsten, antimony, thulium, molybdenum, vanadium, and titanium. It also is rich in coal, iron, lead, zinc, copper, silver, mercury, tin, nickel, phosphorus, asbestos, graphite, and magnesite (Table 2.7).

Table 2.7 Distribution of mineral resources in Northeast Asia sub−region (GOVCN−D; MFA of PRC; CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Specie	157	80	10	280	300
Metal minerals (very large reserves)	Tungsten Antimony Molybdenum Thulium Vanadium Titanium Iron Zinc Lead Silver Mercury Tin Nickel Gold Copper Aluminum Chromium Magnesite	Iron Copper Molybdenum Zinc Silver Gold	—	Iron Copper Lead Zinc Silver Gold	Iron Copper Aluminum Zinc Silver Gold Magnesite
Metalloid minerals (very large reserves)	Coal Oil Natural gas Phosphorus Asbestos Fluorite Barite Silica Steatite Kaoline Graphite	Coal Fluorite Phosphorus Oil	Coal Limestone	Limestone Phosphorus Silica Steatite Fluorite Kaoline Anthracite Mica Asbestos	Graphite Coal Limestone Mica Asbestos

2.1.4 Population

The Northeast Asia sub-region has a total population of 1,508,263,000, about one-forth of the world's total population being distributed in the sub-region. The population density is about 128.km^{-2} (332.mi^{-2}), which can be regarded as one of the most densely-populated areas in the world (Figure 2.2).

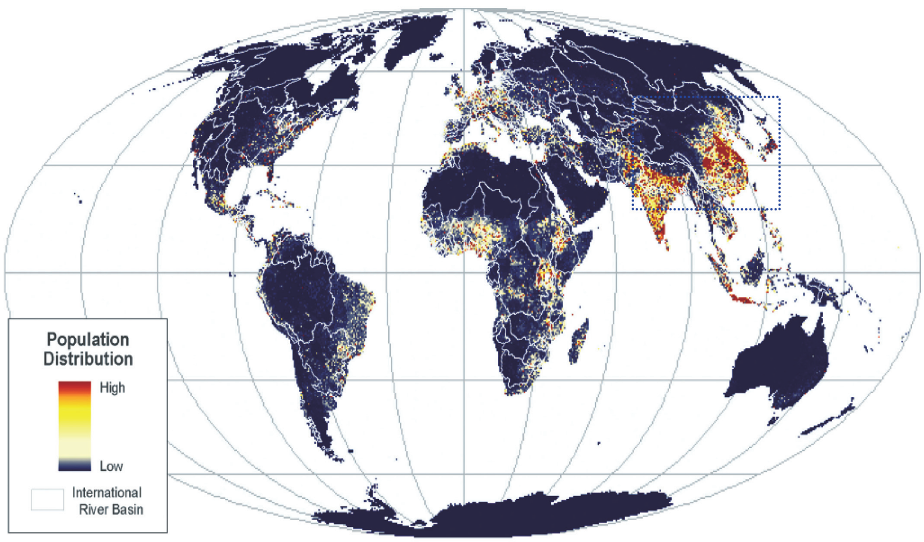

Fig. 2.2 Population density in Northeast Asia sub−region (blue dash rectangle)(UNEP, 2002B)

According to statistics for the last 5 years, the population growth rate of 9.36 per cent exhibits a decreasing trend, compared to the figures for the 1980s and 1990s. At the same time, the aged population is increasing in number in the sub-region. It is reported that Japan, R. Korea, and China entered an "aging stage" in the year 2005, with 17.3, 7.0 and 6.96 per cent, respectively, of the population being above 65 years old. About 42 per cent of the population settled in urban areas in the sub-region in 2002. The urbanization rate is much higher in the developed countries (Japan and R. Korea) than in the developing countries (China and D.P.R. Korea) (Table 2.8).

The Northeast Asia sub-region has 59 nationalities (Table 2.9). China has 56 nationalities, of which the major nationality is Han (91.59 per cent of the population), while Mongolia has 5 nationalities, with Mongolia being the main nationality (90 per cent). Japan has 3 nationalities, with Yamato as the main nationality (98 per cent), while R. Korea and D.P.R. Korea are composed of a single Korean nationality.

Table 2.8 General characteristics of population in Northeast Asia sub–region (MFA of PRC; CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Population (million)	1,307.56	2.56	127.74	47.254	23.149
Population density (person.km^{-2})	135	2	338	474	188
Population growth ratio (per cent)	6.234	17	6.54	9.2	7.85
Ratio of urban population (per cent)	37.63	56.99	78.51	80.30	59.40

Table 2.9 Names of nationalities in Northeast Asia sub–region (GOVCN–E; MFA of PRC)

Sequence number	Name	Sequence number	Name	Sequence number	Name	Sequence number	Name
1	Han	16	Hani	31	Daur	46	Deang
2	Mongolian	17	Kazak	32	Mulam	47	Bonan
3	Hui	18	Dai	33	Qiang	48	Yugur
4	Zang	19	Li	34	Blang	49	Gin
5	Uygur	20	Lisu	35	Salar	50	Tatar
6	Miao	21	Wa	36	Maonan	51	Derung
7	Yi	22	She	37	Gelao	52	Oroqen
8	Zhuang	23	Gaoshan	38	Xibe	53	Hezhen
9	Bouyei	24	Lahu	39	Aching	54	Monba
10	Korean	25	Shui	40	Primi	55	Lhoba
11	Man	26	Dongxiang	41	Tagik	56	Jino
12	Dong	27	Naxi	42	Nu	57	Yamato
13	Yao	28	Jingpo	43	Uzbek	58	Aino
14	Bai	29	Kirgiz	44	Russian	59	Ryukyuan
15	Tujia	30	Tu	45	Ewenki		

Explanation:

1. Nationalities whose sequence numbers are 1~56 belong to P.R. China; 2. nationalities whose sequence numbers are 1, 2, 17, 43, and 44 belong to Mongolia; 3. nationalities whose sequence numbers are 57~59 belong to Japan; 4. nationalities whose sequence number is 10 belongs to R. Korea and D.P.R. Korea.

2.1.5 Economic Development

Excluding D.P.R. Korea, the GDP growth rate of the Northeast Asia sub-region is reported to be 9.275 per cent in 2006, about 1.5 times higher than projections. The total GDP is US$7,635 billion, and US$5,062.capita^{-1}, which is approximately 62 per cent of the world average per capita GDP. The sub-region is rapidly growing economically, but is still far from the global average level. Further, it is large that the difference between the developed countries and developing countries in the sub-region (Table 2.10).

Table 2.10 General introduction of GDP in Northeast Asia sub−region (IMF; WB; CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
GDP growth ratio (per cent)	10.7	18.6	2.8	5	—
Total GDP (billion US$)	2,329	2.27	4,590.5	711.36	2.04
Per capita GDP (US$)	1,352	756	36,486	14,649	85

The Northeast Asia sub-region economic's structure exhibits the following characteristics:

[1] The developed countries in the sub-region (Japan and R. Korea) exhibit a ratio of 1:3:6 among primary, secondary and tertiary industries, indicating their economies are dominated by the tertiary industry, which has entered "post-industrialization" phase. With rapid growth in the high technology and information technology sectors, the service industries of the two countries also have developed rapidly. Up to 2000, Japan's service industries accounted for 19.2 per cent of the overall tertiary industry, which developed as a result of (1) increased software and communication-relevant services; (2) increased demand for health services for an aging society; and (3) growth of other personal services.

[2] China's economic growth has been rapid since the beginning of its economic reform in the later 20th century. According to 2006 statistics, China has a ratio among the primary, secondary and tertiary industries of 12.6, 47.5, and 39.9 per cent, respectively. China entered a period of rapid growth in secondary industries, predominantly steel, electrical, mechanical equipments, automobile, ship-building, chemical industry, electronics, building materials, etc.

[3] D.P.R. Korea's economy is denominated by primary and secondary industries, particularly secondary industries, which account for 50 per cent of the national total production, being mainly supported by mining, metallurgy, machineries, electricity, textile, and chemical industry.

[4] Mongolia is the only country in the sub-region supported by primary production (animal husbandry). Up to 2002, Mongolia had 23.68 million head of livestock. Its secondary industry is mainly light industry, including food processing, mining and energy, being about 23 per cent of its total GDP in 2002.

2.2 Freshwater Resources

2.2.1 Characteristics

The water resources of the Northeast Asia sub-region are generally characterized by a complex influence of geographic and topographic features and climate, including: (1) length of river flows; (2) size of river basins; (3) height of water falls; (4) density distribution of international rivers; and (5) differences among countries. Table 2.11 summarizes general information on the sub-region's water resources, with the data arranged in order from large to small river basin areas.

Table 2.11 Distribution of main river basins in Northeast Asia sub−region (UNEP, 2002A; GOVCN−F; MFA of PRC; Xinhuanet; Myaimarjav and Davaa 1999)

River basin	Area (km^2)	Main stream length (km)	Main river branch	Country (per cent)	Water system
Amur	2,085,900	4,478	1.Songhuajiang 2.Nenjiang 3.Wusulijiang	P.R. China (42.62) Mongolia (9.14) D.P.R. Korea (0.01) Russia	the Pacific Ocean
Changjiang	1,808,500	6,300	1.Jialingjiang 2.Minjiang 3.Yalongjiang 4.Xiangjiang 5.Yuanjiang 6.Wujiang 7.Ganjiang 8.Hanjiang 9.Lishui 10.Zishui	P.R. China	
Huanghe	752,443	5,464	1.Taohe 2.Daheihe 3.Fenhe 4.Weihe	P.R. China	
Zhujiang	453,690	2,214	1.Dongjiang 2.Xijiang 3.Beijiang	P.R. China	

River basin	Area (km²)	Main stream length (km)	Main river branch	Country (per cent)	Water system
Huaihe	269,283	1,000	1.Bailuh 2.East Feihe 3.West Feihe 4.Yihe 5.Shuhe 6.Sihe	P.R. China	the Pacific Ocean
Haihe	263,631	1,090	1.Yongdinghe 2.Daqinghe 3.Luanhe 4.Tuhaimajiahe	P.R. China	
Liaohe	228,960	1,390	1.Laohahe 2.East Liaohe 3.West Liaohe 4.Xinkaihe	P.R. China	
Herlen	116,455	1,090	1.Bogd 2.Tsagaan	Mongolia	
Yalu	61,900	795	—	P.R. China D.P.R. Korea	
Han	45,343	831	1.North Han River 2.South Han River	R. Korea (74.98) D.P.R. Korea (25.02)	
Tumen	33,000	525	—	P.R. China (69.70) D.P.R. Korea	
Onon	29,070	298	—	Mongolia	
Nakdong	25,000	525	1.Nam 2.Geumho	R. Korea	
Daedon	20,300	439	1.Nam 2.Jaenyeong	D.P.R. Korea	
Tonegawa	16,840	322	Edogawa	Japan	
Ishikarigawa	14,330	268	1.Amegougawa 2.Kamikawa 3.Ushishubetsukawa 4.Chuubetsugawa 5.Hajikamigawa	Japan	
Shinanogawa	11,900	367	1.Chikumagawa 2.Saikawa 3.Nakatsugawa 4.Kariyatagawa 5.Ikanashigawa 6.Nakatsugawa	Japan	
Kitakamigawa	10,150	249	—	Japan	

2.2.1.1 River Lengths

The total length of all the rivers in the Northeast Asia sub-region is 493,000 km (306,336 mi), with more than 80 per cent of the rivers being longer than 200 km (124 mi) in length, and about 40 per cent of the rivers being longer than 500 km (311 mi). Due to its narrow land shape, however, the length of rivers in Japan is usually less than 200 km (124 mi), with its longest river (Shinanogawa River) being about 367 km (228 mi) long. More than 95 per cent of the rivers longer than 1,000 km (621 mi) are located in China.

2.2.1.2 River Basin Areas

Based on incomplete statistics, the Northeast Asia sub-region has about 2,000 rivers with basin areas greater than 1,000 km^2 (362 mi^2), and 5,500 rivers with basin areas greater than 100 km^2 (39 mi^2). The CRB in China has 49 tributaries with total basin areas greater than 10,000 km^2 (3,861 mi^2), and 9 tributaries (Jialingjiang River; Minjiang River; Yalongjiang River; Xiangjiang River; Yuanjiang River; Wujiang River; Ganjiang River; Hanshui River) having total basin areas greater than 50,000 km^2 (19,305 mi^2).

2.2.1.3 Hydropower Potential

The Northeast Asia sub-region is dominated by a highland topography. Most of its rivers originate from highland areas higher than 2,000 m (6,562 ft) above mean sea level. Thus, the waters fall from considerable heights, providing a great potential for hydropower resources. According to 2006 statistics, China alone has a potential hydropower capacity of 680,000,000 kw (CSY, 2006).

2.2.1.4 Distribution of International Rivers

There are 10 main international river basins in Northeast Asia sub-region (Figure 2.3), including: (1) Amur River Basin; (2) Han River Basin; (3) Har Us Nur River Basin; (4) Jenisej (Yenisey) River Basin; (5) Lake Ubsa-Nur River Basin; (6) Ob River Basin; (7) Pu-Lun-T'o River Basin; (8) Sujfun River Basin; (9) Tumen River Basin; and (10) Yalu River Basin.

2.2.2 Freshwater Resources Base

Excluding D.P.R. Korea, the total water resources of Northeast Asia are 3,351 km^3, equal to about 1/300 of the world's total. The per capita water resource is 2,221 m^3, equivalent to about 25.7 per cent of the global average (MFA of PRC; CYS, 2006; MSY, 2005). Thus, Northeast Asia is a water scarce sub-region, in terms of both total and per capita water resources availability. Table 2.12 illustrates that large variations also exist among the different countries in the sub-region, with the difference reaching nearly 1:60.

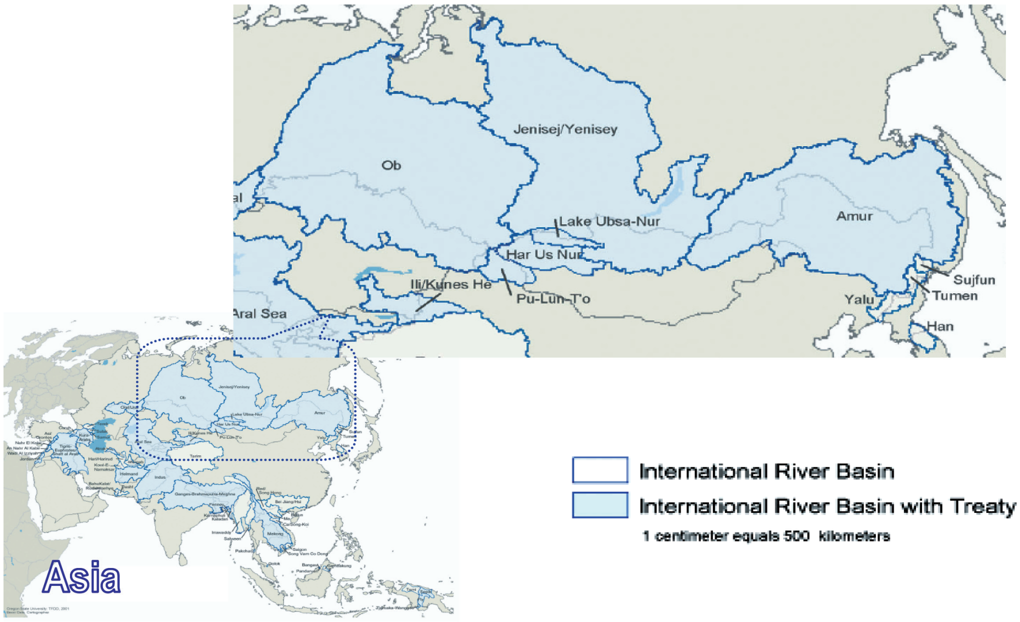

Fig. 2.3 International river basins in Northeast Asia sub−region (UNEP, 2002A)

Table 2.12 Status of freshwater resources in Northeast Asia sub−region (MFA of PRC; CSY, 2006; MSY, 2005)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Total water resources (km^3)	2,800	34.6	400	116	—
Per capita water resources (m^3)	2,152	138,400	3,125	2,389	—

2.2.2.1 Distribution of Precipitation

The Northeast Asia sub-region is relatively rich in precipitation. The annual precipitation is about 1,100 mm (43 in), with an obvious gradient distribution that decreases from east to west, and from south to north (Figure 2.4).

Based on the iso-precipitation lines, the sub-region can be divided into several zones, in terms of moisture conditions, including (1) humid zone; (2) semi-humid zone; (3) semi-arid zone; and (4) arid zone. About 54 per cent of the total land area is in the humid and semi-humid zone, with the remaining 46 per cent being in the semi-arid and arid zones (Tables 2.13 and 2.14). The different countries also exhibit significant variations. Japan and D.P.R. Korea, for example, are in more humid areas, followed by R. Korea. China is mostly semi-humid to semi-arid, while Mongolia is in the very dry zone because of its low precipitation (about 180 mm [7 in] per year) and high evaporation (which can be up to 3-4 times the precipitation rate).

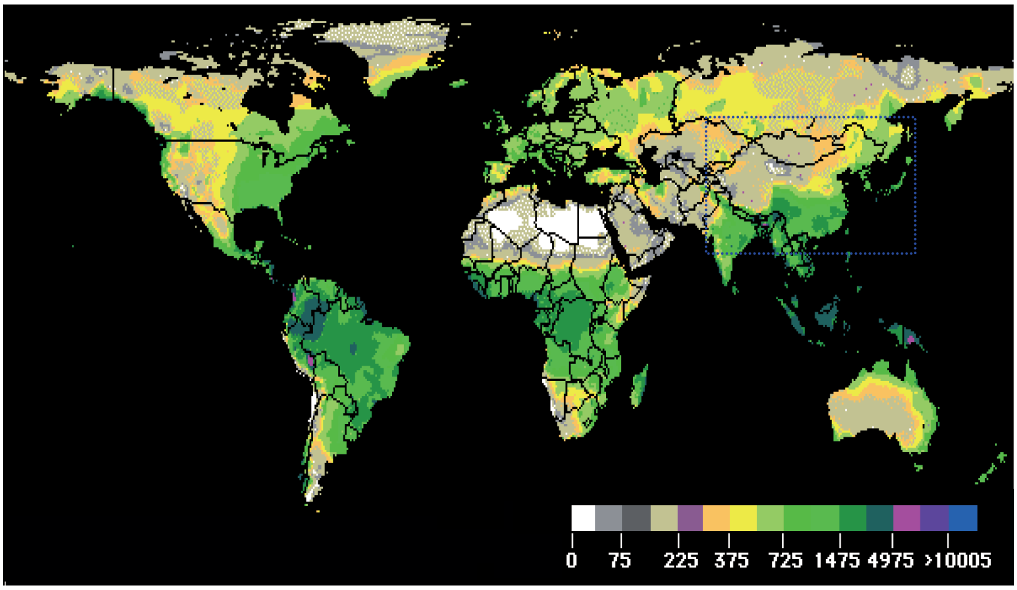

Fig. 2.4 Annual precipitation in Northeast Asia sub–region (blue dash rectangle)(FAO–SDRN Agrometeorology Group, 1997)

Table 2.13 Distribution of humid–arid zones in Northeast Asia sub–region (GOVCN–B; MFA of PRC; CSY, 2006)

		Humid zone	Semi-humid zone	Semi-arid zone	Arid zone
Annual precipitation (mm)		> 800	400 ~ 800	200 ~ 400	< 200
Humid-arid status		Precipitation > Evaporation Evapotranspiration		Precipitation < Evaporation Evapotranspiration	
Vegetation		Forest	Forest-grassland	Grassland	Barren
Distribution range	P.R. China	1.South of QLM-HHR 2.South of QTP 3.Northeast of IMAR 4.East of HLJP, JLP & LNP	1.NEP[1] 2.HBP[2] 3.Most of LP[3] 4.Southeast of QTP	1.South of IMP[4] 2.Remainder of LP 3.Most of QTP	1.West of XJUAR 2.West of IMP 3.Northwest of QTP
	Mongolia	—	—	Northeast Northwest	Most of it
	Japan	All	—	—	—
	R. Korea	Most of it	North	—	—
	D.P.R. Korea	All	—	—	—

Explanation:

1. NEP = Northeast Plain; 2. HBP = Huabei Plain; 3. LP = Loess Plateau; 4. IMP = Inner Mongolia Plateau

Table 2.14 Annual precipitation in Northeast Asia sub–region (MFA of PRC; CSY, 2006)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Annual precipitation (mm)	900	180	1,800	1,500	1,100

Except for Mongolia, the other Northeast Asian countries are strongly influenced by monsoons, particularly the distribution of precipitation. Thus, the sub-region has distinct dry and rainy seasons. The monsoonal circulation predominates during the rainy season, with about 70-80 per cent of the annual precipitation distributed during the monsoon-dominated rainy season (Figure 2.5). The water supply during the dry season normally is from groundwater, water storages and melting snows.

The green line in Figure 2.5 indicates the average annual precipitation in five major river basins (the CRB, HRB and SLB in China; the ORB and TRB in Mongolia) has undergone a decreasing trend over the last half century, from 623.9 mm (24.6 in) in the 1950s to 492.8 mm (19.4 in) in 2006. The frequency of floods and droughts (every 50 years) also has increased over the last 200 years (Figure 2.6), while the occurrence of droughts has increased by 36 per cent. These evidences illustrate an increased vulnerability of water resources in Northeast Asia sub-region.

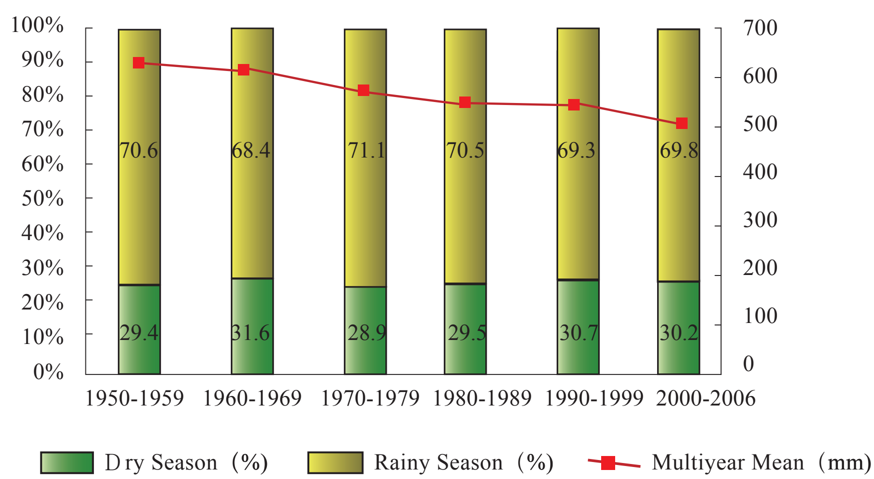

Fig. 2.5 Characteristics of precipitation in Northeast Asia sub–region

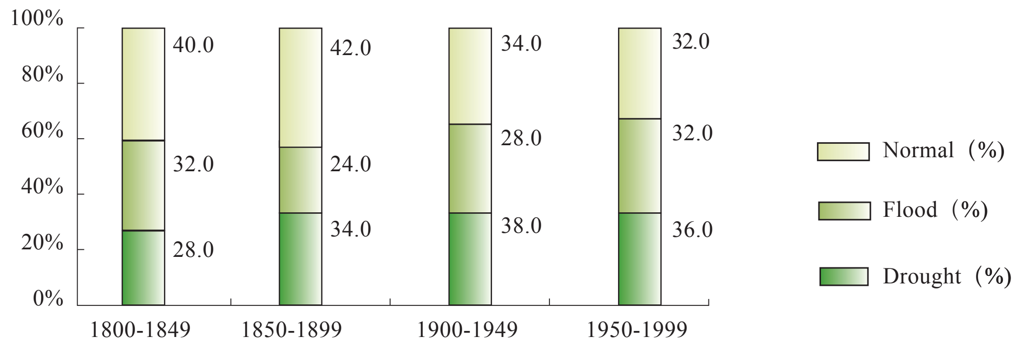

Fig. 2.6 Ratio of drought and flood disasters frequency in Northeast Asia sub–region (Su et al., 2006)

2.2.2.2 Development and Use

Excepting D.P.R. Korea, the total water use in the Northeast Asia sub-region is 684.3 km^3, equivalent to 29.7 per cent of the global total. The per capital water use is 454 $m^3.year^{-1}$, about 1.2 times the world average (Table 2.15), illustrating the sub-region is a water-scarce area.

Table 2.15 Freshwater resources use in Northeast Asia sub–region (MFA of PRC; CSY, 2006)

	P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Total water use (km^3)	563.3	0.4	90	30.6	—
Per capita water use (m^3)	432	160	703	630	—

Most water use in the sub-region is for agricultural production (about 60 per cent of the total water use). Industrial water use is greater than domestic water use in the developing countries, with the opposite situation occurring in the developed countries (Japan and R. Korea). Based on UNESCO data, the per capita domestic water use in the developed countries of the sub-region is about 10 times greater than for the developing countries. At the same time, large-scale reservoirs in the sub-region, which constitute an important means for storing water for hydropower, irrigation, etc., have contributed to increased evaporation of surface water. The total quantity of water evaporated from water surfaces is estimated to be greater than the total industrial and domestic water use. Further, chinese statistics indicate that other water uses (mainly for ecological purposes) are increasing annually (Figures 2.7 and 2.8).

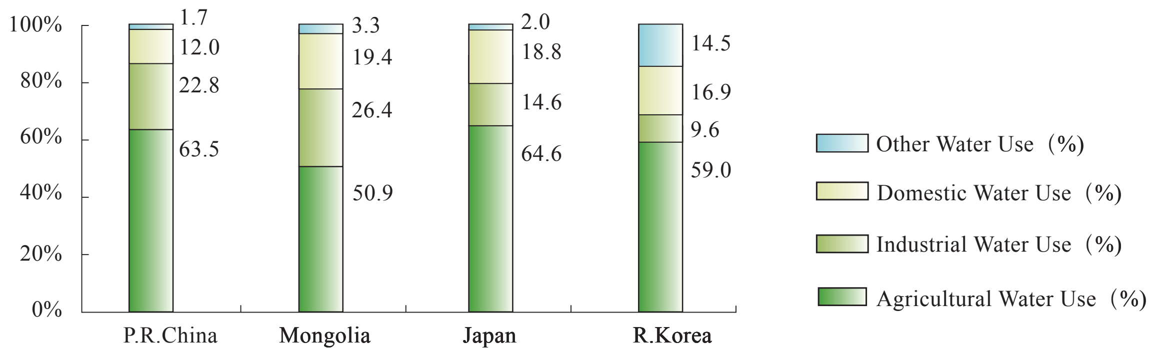

Fig. 2.7 Distribution of water use ratio in Northeast Asia sub–region

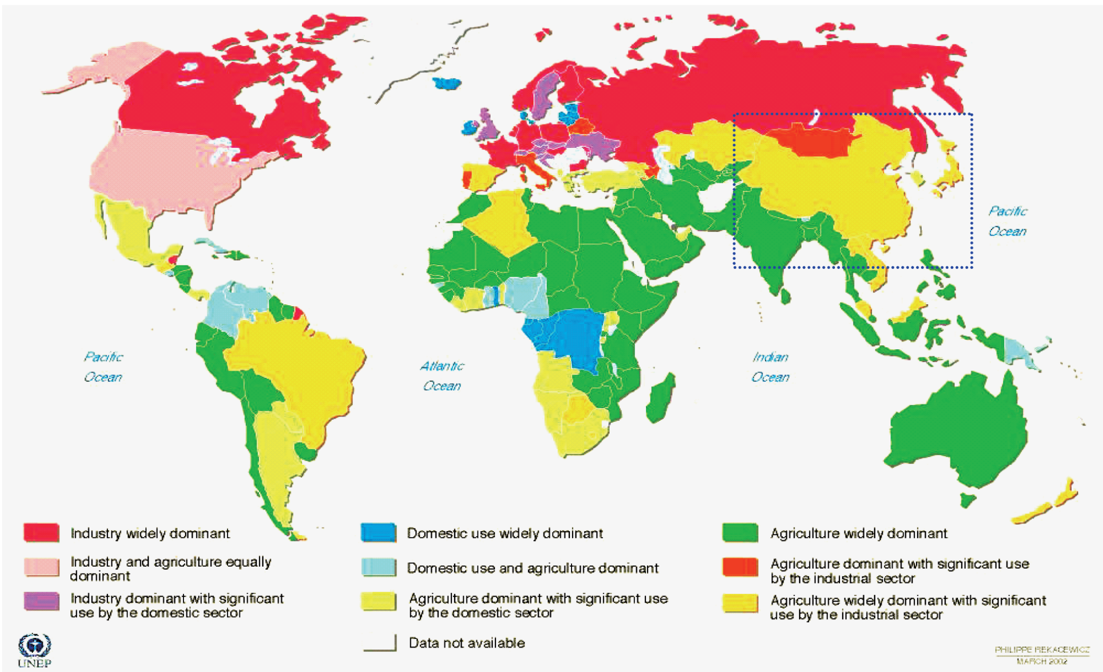

Fig. 2.8 Freshwater withdrawals in Northeast Asia sub–region (blue dash rectangle) (UNEP, 2002B)

Approximately 335,000,000 people experienced limited access to improved drinking water in the Northeast Asia sub-region in 2002 (Table 2.16), equal to about one-third of the population. Compared to 1990, however, the drinking water situation has rapidly improved. During the last 13 years, about 208,000,000 people benefited from various drinking water improvement programs, including 146,000,000 in urban areas (70.2 per cent) and 62,000,000 in rural areas (29.8 per cent) (Tables 2.16 and 2.17). These statistics indicate a positive contribution from implementation of the MDGs, particularly that the proportion of the world's population without access to improved drinking water will be decreased by half.

Table 2.16 Definition of improved drinking water supply and sanitation (ADB, 2006)

Intervention	Improved	Unimproved
Drinking water supply	house connection	unprotected well
	standpost/pipe	unprotected spring
	borehole	water provided by vendor
	protected spring or well	bottled water
	collected rainwater	water provided by tanker or truck
	water disinfected at point-of-use	
Sanitation	sewer connection	service or bucket latrines
	septic tank	public latrines
	pour-flush	latrines with open pit
	simple pit latrine	
	ventilated-improved pit latrine	

Explanation:
1. "Improved" drinking water supply does not automatically mean the water is safe; rather, it denotes that water is more assessable, and that some measures have been taken to protect the water source from contamination; 2. "Improved" sanitation generally involves better access and safer disposal of excreta.

Table 2.17 Drinking water supply in Northeast Asia sub–region (ADB, 2006)

Year	Population (millions of people)			Served population (millions of people)			Un-served population (millions of people)		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
1990	1,351	446	905	994	445	549	357	1	356
2002	1,502	631	871	1,202	591	611	300	40	260
Increase	151	185	-34	208	146	62	-57	39	-96

Table 2.18 indicates the availability of safe drinking water to the population in urban areas has remained essentially unchanged from 1990 to 2002 in the sub-region. A decreasing trend was observed for China, however, based on its fast rate of urbanization over this period of time, thereby resulting in a rapidly increasing urban population (by 180,117,100 over the 13 year period), accompanied by slow development of infrastructure (mostly in the western region of China). In contrast, China exhibited a significant increase in safe drinking water supply for rural areas from 1990 to 2002, as a result of a combination of decreased rural population (by 40,555,000) and new rural development policies (*New Socialism Countryside program*). No similar change has been observed, however, in other parts of the Northeast Asia sub-region. Nevertheless, big urban-rural disparities in regard to drinking water supplies exist throughout the sub-region. In 2002, the safe drinking water availability to urban area populations was 95.2 per cent, compared to a figure as low as 73.8 per cent for rural areas. A large regional disparity also is reported, with a significantly improved situation in the developed countries. Japan and R. Korea, for example, have 100 per cent coverage for the availability of safe drinking water in both urban and rural areas. The coverage is lower in China and D.P.R. Korea, with Mongolia having the lowest coverage among the Northeast Asian sub-region countries.

Table 2.18 Drinking water supply coverage in Northeast Asia sub−region (ADB, 2006)

		P.R. China	Mongolia	Japan	R. Korea	D.P.R. Korea
Urban population (thousands of people)	1990	311,932	1,263	77,916	31,723	11,574
	2002	492,049	1,459	100,295	37,944	13,750
Urban population served (per cent)	1990	100	87	100	97	100
	2002	92	87	100	97	100
Rural population (thousands of people)	1990	843,373	953	45,621	11,146	8,382
	2002	802,818	1,100	27,145	9,486	8,791
Rural population served (per cent)	1990	59	30	100	—	100
	2002	68	30	100	71	100

2.2.2.3 Ecological Health

The Northeast Asia sub-region has about 30,000 lakes, with about 2,800 lakes having surface areas larger than 1 km^2 (0.37 mi^2). As natural reservoirs, lakes have an important role in storing and buffering waters, as well as functioning as an important component of wetland ecosystems. With the expansion of agricultural land and water usage (land reclamation, excessive irrigation), lake ecosystems have been subjected to large pressures, with a decrease in the total water surface area. Other factors also influence the health of lake ecosystems in the sub-region, an example being deposition of sediment because of erosion from mining, deforestation, etc. For instance, the TRB had 8 lakes dry up or disappear over the past 10 years, accounting for 7.25 per cent of its total number of lakes.

Water quality deterioration is another crucial problem in the Northeast Asia sub-region. According to official Chinese statistics for 2006, of its 7 major water systems, 41 per cent of the water bodies could reach water quality standard III, but actually decreased by 1 per cent, compared to the previous year. Further, 32 per cent of the water bodies exhibit a water quality standard IV-V, an increase of 2 per cent. In addition, 27 per cent of the water bodies exhibit a water quality standard below V, a decrease of 1 per cent from the previous year. The main water pollutants include ammonia-nitrogen, petroleum, permanganate, volatile phenols, and biochemical oxygen demand (BOD)(GOVCN-G) .

2.2.2.4 Management

For a region with a severe shortage of water resources, a crucial measure for trying to balance water supplies and water demands is to increase water use efficiency. Water use efficiency, in turn, is a function of a number of variables, including technology, costs, knowledge, etc. As a very important cost indicator, the WUGDP reflects the achievements of the governments in water savings and environmental protection.

Excluding D.P.R. Korea, the Northeast Asia sub-region has achieved a water use efficiency of US\$11.11.m^{-3}, about 10 per cent below the world average (Figure 2.9). Mongolia exhibits the lowest value, followed by China and R. Korea. Japan exhibits the highest value, illustrative of the similar per capita GDP in the sub-region, demonstrating that a country exhibits a higher water use efficiency with increasing economic development. Thus, the sub-region exhibits large variations in water use efficiency between the developed and developing countries. Mongolia's water use level per unit GDP, for example, is about 28.6 per cent of the world average, and only about 1/15th that of Japan.

The Northeast Asia sub-region had about 751,000,000 people without access to improved sanitation in 2002, with 78.3 per cent being distributed in rural areas. Nevertheless, there is now an increasing number of people in the sub-region with access to improved sanitation, compared to 1990. During the period 1990-2002, about 327,000,000 people benefited from sanitation improvement programs, including 150,000,000 in urban areas (45.9 per cent) and 177,000,000 in rural areas (54.1 per cent) (Tables 2.19 and 2.20).

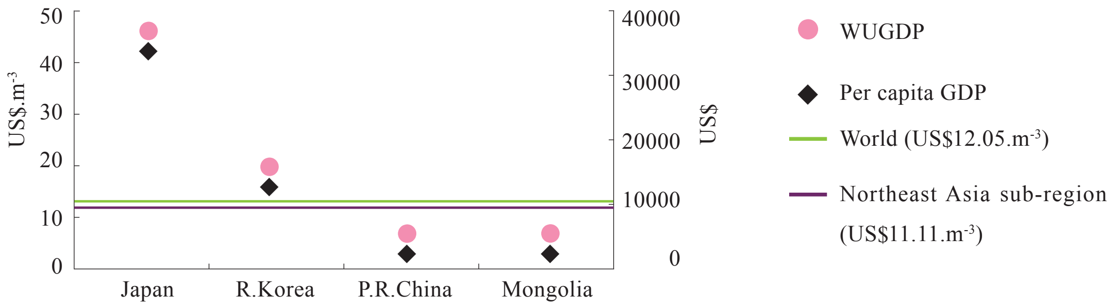

Fig. 2.9 Water use efficiency state in Northeast Asia sub−region (MFA of PRC, Xinhuanet, and CYS, 2006)

Table 2.19 Sanitation in Northeast Asia sub−region (ADB, 2006)

Year	Population (millions of people)			Served population (millions of people)			Un-served population (millions of people)		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
1990	1,351	446	905	424	318	106	927	128	799
2002	1,502	631	871	751	468	283	751	163	588
Increase	151	185	-34	327	150	177	-176	35	-211

Table 2.20 Sanitation coverage for two countries in Northeast Asia sub−region (ADB, 2006)

		P.R. China	Japan
Urban population (thousands of people)	1990	311,932	77,916
	2002	492,049	100,295
Urban population served (per cent)	1990	64	100
	2002	69	100
Rural population (thousands of people)	1990	843,373	45,621
	2002	802,818	27,145
Rural population served (per cent)	1990	7	100
	2002	29	100

China increased its total sanitation access by 67 per cent by the year 2002, as a result of a 6 per cent compounded annual rate of expansion. The total coverage grew by 8 per cent in its urban areas (from 23 per cent to 44 per cent) over the 12-year period. China increased its rural sanitation coverage by a remarkable 150 per cent over the same period (7 per cent in 1990 to 29 per cent in 2002). About 300 million people in China gained access to improved sanitation facilities during this period. Although exhibiting a lower percentage in rural gains, the 8 per cent growth in urban sanitation coverage is remarkable in view of the rapid urbanization rate in China. Although The 13 per cent annual increase in rural sanitation translates into nearly 174 million rural Chinese gaining accesses, the rural sanitation coverage only reached 29 per cent by 2002. Thus, despite the progress made, more than 725 million people in China alone do not have access to improved sanitation facilities – representing more than a quarter of all the people in the world without adequate sanitation coverage (ADB, 2006).

The complex physical, political, and human interactions within international river basins make the management of these shared water systems especially difficult. Issues of increasing water scarcity, degrading water quality, rapid population growth, unilateral water development, and uneven levels of economic development are commonly cited as potentially disruptive factors in co-riparian water relations. This combination of factors has led academics and policymakers alike to warn of impending conflicts over shared water resources. To prevent potential conflict and resolve existing disputes, the international community has focused considerable attention in the 20th century on developing and refining principles of international freshwater management (UNEP, 2002A). A list of agreements signed among countries sharing international rivers is summarized in Table 2.21.

Table 2.21 International freshwater agreements in Northeast Asia sub–region (UNEP, 2002A)

River basin	Signatories	Date	Treaty Name
Amur	P.R. China Union of Soviet Socialist Republics	1956-08-18	Agreement between Union of Soviet Socialist Republics and People's Republic of China on joint research operations to determine the natural resources of the Amur River Basin, and the prospects for development of its potential productivity, and planning and survey operations to prepare scheme for multi-purpose exploitation of the Arugun and Upper Amur Rivers.
	P.R. China Mongolia	1994-04-29	Agreement between People's Republic of China and Mongolia on protection and utilization of transboundary waters

River basin	Signatories	Date	Treaty Name
Amur	Mongolia Russian Federation	1995-02-11	Agreement between Mongolia and Russian Federation on protection and use of transboundary waters
Har Us Nur	P.R. China Mongolia	1994-04-29	Agreement between People's Republic of China and Mongolia on protection and utilization of transboundary waters
	Mongolia Russian Federation	1995-02-11	Agreement between Mongolia and Russian Federation on protection and use of transboundary waters
Yenisey (Jenisej)	Mongolia Russian Federation	1995-02-11	Agreement between Mongolia and Russian Federation on protection and use of transboundary waters
Lake Ubsa-Nur	Mongolia Russian Federation	1995-02-11	Agreement between Mongolia and Russian Federation on protection and use of transboundary waters
Pu-Lun-T'o	P.R. China Mongolia	1994-04-29	Agreement between People's Republic of China and Mongolia on protection and utilization of transboundary waters
	Mongolia Russian Federation	1995-02-11	Agreement between Mongolia and Russian Federation on protection and use of transboundary waters

3 Freshwater Resources Vulnerability Assessment

Based on the general description of its water resources, a more systematic analysis of the vulnerability of the freshwater resources was implemented for the Northeast Asia sub-region. With the joint efforts of partners in China and Mongolia, 5 major river basins were identified for detailed analyses, including the Changjiang, Huanghe and Songliao River Basins in China, and the Orkhon and Tuul River Basins in Mongolia. Detailed reports for these basins are attached as appendices to this report. This section of this report synthesizes the main results from these analyses.

3.1 Description of Selected River Basins

3.1.1 Changjiang River Basin

The Changjiang River flows from west to east, with a total length of 6,300 km (3,915 mi) and a drop height of 5,400 m (17,717 ft). Its geographic coordinates are 90°33′ to 122°25′E in longitude, and 24°30′ to 35°45′N in latitude. It is 3,000 km (1,864 mi) in length from west to east, and 1,000 km (621 mi) from north to south, with a total basin area 1,808,500 km^2 (698,266 mi^2), accounting for about 18.75 per cent of the total area of China.

The CRB exhibits various topographical features, with about 84.7 per cent of the basin area being occupied by mountains, plateaus and highlands, 11.3 per cent by plains, and 4 per cent by water.

The CRB lies in 3 different climate zones, including the Qinghai-Tibetan cold climate, southwest tropical monsoon climate, and semi-tropical monsoon climate in the middle of China. The annual mean temperature is 16-18 °C (61-64 °F) throughout most of the CRB. Being influenced by the monsoon climate, about 70-90 per cent of the precipitation occurs during May to October.

Based on data from the year 2004, 221,800 km^2 (85,637 mi^2) of the CRB area is classified as arable land (13.5 per cent), 480,000 km^2 (185,329 mi^2) is forest land (29.2 per cent), and 300,000 km^2 (115,830 mi^2) is pasture land (18.3 per cent). The arable land is limited to only 5,100 $m^2.capita^{-1}$ (474 $ft^2.capita^{-1}$), which is not only lower than the global average value of 36,700 m^2.capita (3,413 $ft^2.capita^{-1}$), but also under the threshold warning value of 5,300 $m^2.capita^{-1}$ (493 $ft^2.capita^{-1}$) proposed by the FAO in the same year.

The CRB had a rural population of 285.37 million people, and an urban population of 194.63 million people in 2005, accounting for 36.71 per cent of China's total population. The mean population density exceeded 265 persons.km^{-2} (686 persons.mi^{-2}), nearly twice the national average.

The GDP of the CRB was 6,464.62 billion RMB in 2005, accounting for 35.31 per cent of China's total GDP. There is a distinct difference in the level of economic development between the upper, middle, and lower reaches of the CRB. The per capita GDP in the lower reach, for example, was approximately 50 per cent greater than that of the middle reach, and approximately twice that of the upper reach.

The CRB is one of China's most water resource-rich regions. The total water resource (i.e., the total river runoff and groundwater volume after reduction of the duplicated portion) is about 1,028.52 billion m^3. The multi-year (1997 to 2004) mean precipitation is 1,091 mm (43 in), yielding a total water volume of 1,973.07 billion m^3. This value is about 1.2 times higher than the national multi-year mean precipitation, making the CRB a region with abundant rainfall. The multi-year (1997 to 2004) mean river runoff is 973.73 billion m^3. It is estimated that about 242.31 billion m^3 of groundwater was extracted annually during 1997-2004. Due to the influence of topography and climate, however, this volume isn't distributed equally in space or time.

The total water supply in the CRB has varied between 170 and 180 billion m^3, and rising steadily in recent years. The annual mean water supply volume was 172.58 billion m^3 from 1998 to 2004, including 164.18 billion m^3 of surface water and 8.23 billion m^3 of groundwater. During the same period, the mean annual water use volume was 171.891 billion m^3, including 57 per cent for agricultural use, 32 per cent for industrial use, and 11 per cent for domestic use.

Water pollution in the CRB is currently a very serious problem. Based on the most recent data, 90 per cent of the water in Taihu Lake is in the Class V category, no longer being suitable for drinking water. The current area of soil erosion in the region is 106.3 thousand km^2 (410,427 mi^2), which has resulted in a shrinking lake area in the CRB. The total lake area was only 12,000 m^2 (129,167 ft^2) in the 1980s, being only about 45.5 per cent of that existing in the 1950s.

The Chinese government has paid much attention to water resources management. To this date, more than 10 national laws were issued in regard to water resources management. Although water use efficiency in the CRB exhibited a constant upward trend during 1999-2004, it was still relatively low because the WUGDP reached about US$4.$m^{-3}$, far less than the global average level of US$12.05.m^{-3}, in 2004. The current state of accessibility to adequate sanitation facilities, however, remains poor.

The Changjiang River is not an international river, so there is no concern in regard to transboundary issues. The CRB, however, covers a large land area, with a large variation in biophysical and socioeconomic conditions. Water use conflicts among different reaches, therefore, remain a crucial issue in the CRB.

3.1.2 Huanghe River Basin

The Huanghe River flows from west to east, with a total length of 5,464 km (3,395 mi), and a drop height of 4,480 m (14,698 ft). Its geographic coordinates are 95°53′ to 119°05′E in longitude, and 32°10′ to 41°50′N in latitude. It is 1,900 km (1,181 mi) long from west to east, and 1,100 km (684 mi) long from north to south, with a total area of 795,000 km^2 (306,951 mi^2), including 42,000 km^3 of endorheric basin, accounting for about 8.28 per cent of the total area of China.

Generally speaking, there are 4 typical topographic sections, from west to east, in the HRB, including the Qinghai-Tibetan Plateau, Inner Mongolia Plateau, Loess Plateau, and Huang-Huai-Hai Plain. The river banks are higher in the lower reaches than in the surrounding area, thereby also known as the hanging river.

Because most of it is located far from the sea, the HRB belongs to the continental monsoon climate. The annual mean temperature is 1-8 ^{o}C (34-46 ^{o}F) in the upper reaches, 8-14 ^{o}C (46-57 ^{o}F) in the middle reaches, and 12-14 ^{o}C (54-57 ^{o}F) in the lower reaches. Being influenced by the monsoon climate, about 70-80 per cent of the annual precipitation occurs during June to September.

Based on 2003 data, 132,633 km^2 (51,210 mi^2) of the HRB is arable land (16.7 per cent), 102,013 km^2 (39,387 mi^2) is forest land (12.8 per cent), and 279,427 km^2 (107,887 mi^2) is pasture land (35.1 per cent). The forests are distributed mainly in the lower reaches, while the pastures are distributed mainly in the upper and middle reaches.

The rural population in the HRB in 2005 was 251.22 million people, and the urban population was 149.03 million people, accounting for 30.61 per cent of China's total population. The mean population density in this basin exceeds 503 persons.km^{-2} (1,303 persons.mi^{-2}) which is nearly four times the national average. The HRB, especially its middle and lower reaches, is one of the most populous areas in China.

The GDP of HRB in 2005 was 5,132.35 billion RMB, accounting for 28.03 per cent of China's total GDP. The HRB has been a key agricultural development area in China for a long period, while its industry is dominated by natural resource-based production. More than 50 per cent of the coal production of China, for example, is from the HRB, while its petroleum production has reached about 25 per cent of the national total.

The HRB is one of the most water-scarce regions in China. The water resources total about 59.78 billion m^3. The multi-year (1997 to 2004) mean precipitation is 336.6 mm (13.25 in), yielding a total water volume of 267.6 billion m^3, equal to 37.4 per cent of the national multi-year mean precipitation. The multi-year (1950 to 2000) mean river runoff is 57.2 billion m^3. About 80 per cent of precipitation returns to the atmosphere via evapotranspiration, with only about 20 per cent retained as river runoff. The annual mean groundwater resources (1997 to 2004) are estimated to be about 40.09 billion m^3. About 70 per cent of the precipitation occurs during the short rainy season, increasing the probability of droughts and floods.

The total water supply in the HRB in 2004 reached 37.2 billion m^3, accounting for 59.2 per cent of the total water resources. The water supply gradually decreases as one moves from the upper (47.6 per cent) to the middle (31.0 per cent) to the lower (21.4 per cent) portion of the basin. Surface water provides a high proportion of the water resources in the upper and lower reaches, while groundwater extraction and use is high in the middle reaches. The annual mean water use was 38.8 billion m^3, during 1995-2004, including 77.2 per cent for agricultural use, 14.4 per cent for industrial use, and 8.4 per cent for domestic use. About 38.6763 million people lacked access to safe drinking water in 1995, as well as 25.258 million livestock.

The annual soil loss in the middle reaches of the HRB is about 1.6 trillion kg (1.6 billion tons), being the main cause of sedimentation. Further, the sedimentation process also raises the river bed, making the Huanghe River the most dangerous suspending river in the world. Wastewater discharges in the HRB have doubled over the last 20 years, and are still increasing, while the river's water quality has downgraded by two levels (more than 60 per cent being classified as Class IV or worse).

The HRB water resources are used mainly for agricultural production, with a low commercial value. The water resources are also undervalued even for industrial and domestic use. During 1999-2004, the WUGDP in the upper, middle and lower reaches was about 0.74, 3.57, 1.82 US\$.m^{-3}, respectively, being far below the global average level of 12.05 US\$.m^{-3} in 2004.

HRB is a relatively less-developed region in China, with 269 of the nation's 592 poorest counties being located in this basin. The sanitary facilities in most rural areas remain inadequate.

The HRB is not an international river basin, but does flow through 9 provinces or regions within China, with management conflicts still possible among its different provinces or regions.

3.1.3 Songliao River Basin

The SLB is generally divided into two independent river sub-basins, including the Songhuajiang River Basin (SHJRB) and the Liaohe River Basin (LHRB), being named administratively, rather than geographically. The SLB refers to the sub-basins of the Songhuajiang River, Liaohe River, rivers around the Huanghai and Bohai Seas, and several important international rivers in northeast China (e.g., Amur, Sujfun, Tumen, and Yalu Rivers).

The geographic coordinates of the SLB are 116°26′ to 135°05′E in longitude, and 40°30′ to 53° 34′N in latitude. The SLB has a large water network system, with a total area of 1,249,000 km^2 (482,240 mi^2) accounting for about 13.01 per cent of the total area of China. The proportion of landform areas in the SLB includes mountains (43.8 per cent), highlands (28.4 per cent), plains (28.4 per cent), and other land forms (1.4 per cent).

Most regions of the SLB have climate characteristics of the westerlies, while a few in the northeast portion of the basin are in the temperate continental monsoon climate. The annual mean temperature is 3-8 ^oC (37-46 ^oF), with the mean relative humidity being 50-75 per cent. Under the influence of the monsoon climate, about 60-80 per cent of the annual precipitation occurs during June to September.

Based on 2006 data, 251,000 km^2 (96,912 mi^2) of the SLB land area is classified as arable land (20.2 per cent), 566,000 km^2 (218,534 mi^2) as forest land (45.6 per cent), and 212,600 km^2 (82,085 mi^2) as pasture land (17.1 per cent). The arable land is mainly located on the Songnen, Sanjiang and Liaohe Plains, one of the three large “dark soil” regions in the world.

The SLB also has abundant natural resources, including the above-noted fertile “dark soil,” the best grasslands and forests in China, and various varieties of mineral resources. The oil and coal reserves in the SLB comprise over half and one-tenth, respectively, of the total quantities in China.

Based on 2003 statistics, the SLB had a rural population of 62.95 million people, and an urban population of 56.06 million people, accounting for 9.2 per cent of China’s total population. The mean population density in the basin was 95 persons.km^{-2} (280 persons.mi^{-2}), only about 70 per cent of the national average. In the same year, the GDP of the SLB was 1,362.5 billion RMB, accounting for 11.6 per cent of China’s total GDP.

The SLB is one of the most water resource-rich regions in China. The water resources total about 199 billion m^3. Its multi-year (1956 to 2000) mean precipitation is 515 mm (20.3 in), yielding a total water volume of 643.2 billion m^3, about 57.2 per cent of the national multi-year mean precipitation. The mean precipitation in sub-river basins, however, is 505 mm (19.9 in) and 545 mm (21.4 in) in the SHJRB and the LHRB, yielding total water volumes of 471.9 and 171.3 billion m^3 respectively. The multi-year (1956 to 2000) mean river runoff is 170.4 billion m^3, including 75.8 per cent from the SHJRB and 24.2 per cent from the LHRB. There is an estimated annual volume of 68 billion m^3 of groundwater resources (based 1956-2000 data), including 70.3 per cent from the SHJRB and 29.7 per cent from the LHRB. The water resources in the SLB, however, vary markedly both in space and time, with more water being available in the central basin, and less in the middle and western regions.

From 1999-2004, the annual mean water supply volume in the SLB was 58.34 billion m^3, including 32.03 billion m^3 of surface water and 26.31 billion m^3 of groundwater. Compared to the national average of 20 per cent, the CRB average of 4.75 per cent, and the HRB average of 35.6 per cent, the exploitation ratio of groundwater in the SLB (46.6 per cent) is very high. Over-exploitation of the groundwater resource has taken place in recent years. During this period, the total mean annual volume of water use was 57.98 billion m^3, including 70.6 per cent for agricultural use, 21.0 per cent for industrial use, and 8.4 per cent for domestic use. About 50 per cent of the population is currently classified as rural population with poor access to safe drinking water because of the uneven distribution of water resources.

The SLB has the most and largest wetlands in China, with the total wetland areas covering about 106,069 km^2 (40,953 mi^2), accounting for 8.5 per cent of the basin's total land area. Because of its high vegetation coverage, the sand capacity in the SHLRB rivers is low. Factors such as droughts, high ratio of land cultivation, and low vegetation coverage, however, lead to serious soil erosion and high sand capacity in the rivers falling under the LHRB.

As one of the problems characteristic of old industrial bases, the sewage discharge volume in the SLB is very high, and the disposal rate is low, thereby resulting in deteriorating surface water quality. In 2002, about 5.72 trillion kg (6.3 billion tons) of sewage was discharged into the rivers, accounting for about 4.58 per cent of the total water resources (nearly 1.6 times the national average).

Although the water use efficiency in the SLB presented a constant upward trend from 1999 to 2004, it is still relatively low, mainly because the WUGDP was about US\$3.03.m^{-3}, far below the global average of US\$12.05.m^{-3} in 2004.

The water supply is important, not only as a safe drinking source, but also for securing adequate sanitation. Based on 2005 statistics, the mean coverage of hygienic toilets in the rural areas of the SLB was only 51.3 per cent, with the mean rate of non-hazardous treatment of night soil being only 57.3 per cent.

Although the SLB contains many international rivers, it is usually not the focus of available water resources in the basin because water use exploitation is relatively low in its rivers. Because the SLB covers a large land area, and has an anfractuous water network system, water use conflicts among different regions remain a crucial issue.

3.1.4 Orkhon River Basin

The Orkhon River is one of the most important rivers in central Mongolia, with a total length of 1,124 km (698 mi), and a drop height of 1,979 m (6,493 ft). The ORB covers 83,012 km^2 (32,051 mi^2), accounting for about 5.3 per cent of the total area of Mongolia.

The ORB flows through 2 typical topographic sections, including: (1) Khangai Mountain Range, with a top altitude of 3,179 m (10,030 ft) in the upper reaches, and containing some sharp craggy mountains; and (2) a river valley in the lower reaches, with a mean altitude of 1,200-1,400 m (3,937-4,593 ft).

The ORB has a continental climate, being characterized by low precipitation and high evaporation. The annual mean temperature is about 2.3 ^oC (36 ^oF). Being under the influence of Mongolian anticyclone, about 70 per cent of the annual precipitation occurs during July to August.

Based on 2002 data, 3,616 km^2 (1,396 mi^2) of the ORB is arable land (4.4 per cent), 24,738 km^2 (9,551 mi^2) is forest land (29.8 per cent), and 48,569 km^2 (18,753 mi^2) is pasture land (58.6 per cent), with pasture land being the predominant land use.

The total population of the ORB is 344,940 inhabitants, based on 2005 data, accounting for 13.9 per cent of the total population of Mongolia. The mean population density in this basin was only about 4 persons.km^{-2} (10.4 persons.mi^{-2}), equivalent to 0.88 per cent of the average value in Northeast Asia sub-region. This makes the ORB one of the most under-populated areas in the world. The GDP of ORB was 417.07 billion TUGRUG during this same period, accounting for 10.2 per cent of Mongolia's total GDP.

The total water resources in the ORB are about 5.06 billion m^3. The multi-year (1940 to 2004) mean precipitation is 307.4 mm (12.1 in), yielding a total water volume of 25.52 billion m^3. This value is about 1.7 times more than the national multi-year mean precipitation, meaning the ORB is a region with abundant rainfall. The multi-year (1945 to 2004) mean river runoff is 4.5 billion m^3. Further, an estimated 1.32 billion m^3 of groundwater resource is available annually. Because of its relatively low population density, the water resources per capita is

16,338.7 m^3, about 9-10 times the global safe level.

The annual mean water supply volume in the ORB during 1996-2002 was 96 million m^3. During the same period, the mean annual water use volume was 20.43 million m^3, comprising 20 per cent for agricultural use, 54 per cent for industrial use, and 23 per cent for domestic use. The water quality in the ORB is presently very good, 75 per cent belonging in Class I & II, and 25 per cent of which belongs in Class III.

Some springs and lakes in the ORB have gradually shrunk and disappeared in recent years because of the combined impacts of overgrazing and over-irrigation. There also is an increasing trend in water pollution in the lower reaches of the ORB since 1985, because of the development of mining and gravel extraction, with nitric acid and phosphor being major pollutants.

3.1.5 Tuul River Basin

The Tuul River is one of the most important rivers in central Mongolia, flowing from east to west and with a total length of 704 km (437 mi). The TRB covers 49,841 km^2 (19,244 mi^2), accounting for about 3.2 per cent of the total area of Mongolia.

The TRB flows through 2 typical topographic sections, including: (1) Khentei Mountain Range, with a top altitude of 2,000 m (6,562 ft) in the upper reach, and with some sharp craggy mountains; and (2) highlands and plains covered with forest and steppe in the lower reach.

The TRB exhibits a continental climate, being characterized by low precipitation and high evaporation. The annual mean temperature is about -4.8 ^oC (-23 ^oF). Under the influence of the Mongolian anticyclone, about 80-90 per cent of the precipitation occurs during June to August.

Based on 2002 data, the TRB contains 727 km^2 (281 mi^2) of arable land (1.5 per cent), 1,447 km^2 (559 mi^2) of forest land (2.9 per cent), and 40,016 km^2 (15,450 mi^2) of pasture land (80.2 per cent), with pasture land being the predominant land use.

Based on statistics from 2000, the population of the TRB was 871,815 inhabitants, accounting for 36.7 per cent of Mongolia's total population. The mean population density in this basin was about 18 persons.km^{-2}, (46.6 persons.mi^{-2}), only about 7.93 per cent of the average value of the Northeast Asia sub-region. Thus, the TRB is one of the most under-populated areas in the world. During this same period, the GDP of TRB was 1,272.9 billion TUGRUG, accounting for 31.1 per cent of Mongolia's total GDP.

The total water resources availability in the TRB is about 1.28 billion m^3. The basin's multi-year (1940 to 2004) mean precipitation is 284.7 mm (11.2 in), yielding a total water volume of 14.19 billion m^3. This volume is about 1.6 times greater than the national multi-year mean precipitation, meaning this region receives abundant rainfall. The annual mean evaporation however, is about 800-900 mm (31.5-35.4 in), about 2.8 times higher than the precipitation. The multi-year (1940 to 2004) mean river runoff is 1.02 billion m^3. An estimated annual volume of 0.25 billion m^3 of groundwater resources is available. Because of its relatively low population density, the per capita water resource in the TRB is 1,468.2 m^3, very close to the global safe level.

During 1997-2004, the annual mean water supply in the TRB was 58.11 million m^3, about 95 per cent being from groundwater resources. During this period, the volume of annual mean water use was 53.43 million m^3, including 9.1 per cent for agricultural use, 50 per cent for industrial use, and 40.9 per cent for domestic use. Livestock water uses accounted for a major portion of the water used for agricultural purposes.

There are 84 rivers and streams, 58 lakes, and about 106 springs in the TRB. Eight rivers, 8 lakes and 16 springs gradually dried up over the last decade, however, because of intensive human activities (overgrazing).

Many small private industries were established in the TRB during its transition to a market economy period (1990-2000). About 60 per cent of the wastewater is pumped, with only 40 per cent being treated with physical, chemical or biological methods. The remaining wastewater is discharged directly into rivers in the basin. As a result, the water quality in the lower reaches of the TRB has been downgraded to Class V, although it is still in the Class II category in the upper reaches of the basin.

3.2 Integrated Analysis

Based on the identified problems in the 5 selected river basins in the Northeast Asia sub-region, the integrated analysis in this section will focus on the following 4 aspects of vulnerability: (1) water resources base; (2) water resources development and use; (3) water resources for ecological health; and (4) water resources management (Table 3.1).

3.2.1 Water Resources Base

Water resources are a primary concern because of their indispensable role in providing fundamental support for people's livelihoods, regional economic development and ecological health. Based on data on the 5 selected river basins, however, the per capita water resources are as low as 1272.07.m^{-3}, equivalent to only about 14.7 per cent of the global average. Thus, this sub-region is one of the world's water-scarce areas.

Table 3.1 Framework for in–depth vulnerability assessment of freshwater resources

Key freshwater resources issues in Northeast Asia sub-region	
Resources base	➞ Water scarcity ➞ Water variation
Development and use	➞ Stresses in water use ➞ Improved drinking water supply accessibility
Ecological health	➞ Ecosystem deterioration ➞ Water pollution
Management capacity	➞ Water use efficiency ➞ Improved accessibility to sanitation ➞ Conflict management capacity

The main element that modulates the water resource base of a region (in addition to its specific geographic locations and other common natural factors influencing the distribution of precipitation), is climate change. A changing climate, including global warming, has already greatly affected the water balance between precipitation and evaporation, etc. There are 3 different climate types and 5 topographic categories among the 5 selected river basins. Thus, all four different humidity types are experienced in all the river basins. In the semi-humid, semi-arid and arid zones, reducing trends of precipitation and runoff are observed, the rate of change is accelerating, and water is becoming a more-and-more scarce resource, with some rivers even partially drying out. According to hydrological records since 1919, the HRB began experiencing a partial dry out in 1972, and a continuous cut-off was observed after 1987. Entering the 1990s, the commencement of the cut-off has advanced in time annually with an increasing frequency of occurrences (Figure 3.1).

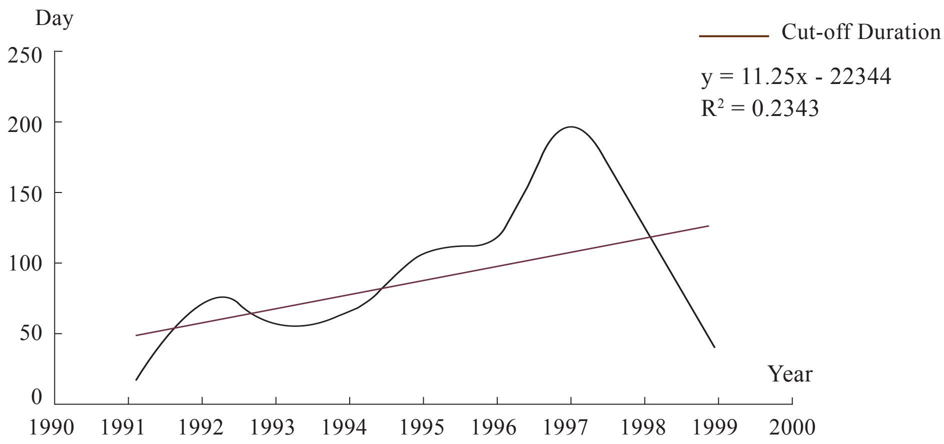

Fig. 3.1 Cut–off duration of Huanghe River observed at Lijin hydrological station (Che and Wang, 2002)

The continuous population increase and expansion of urbanization, at the same time, has resulted in increased socioeconomic pressures on the water resources base. One crucial problem is the over-mining of groundwater because of concentrated water use in urban and industrial centers. As an example, the water table in the TRB (1998) has dropped to 3.1 m (10.17 ft) below the land surface, about twice that observed in 1948, and is continuing (Figure 3.2).

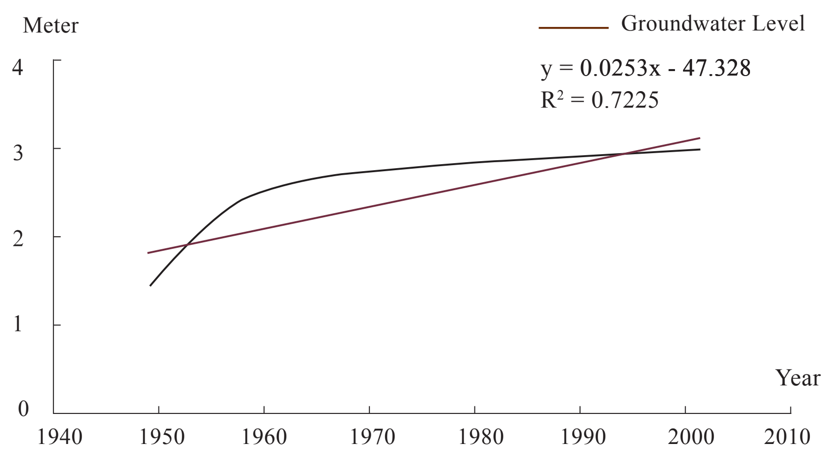

Fig. 3.2 Groundwater table in Ulaanbaatar in the TRB

An increasing trend of precipitation and runoff also has been reported for the humid zone, particularly over the past 10 years, with an obvious influence from the monsoon on precipitation, and about 70-80 per cent of the annual precipitation occurring during June to September. Thus, floods become a major problem in these areas during the rainy season.

There is an obvious trend of increased frequency of floods in the CRB. Figures 3.3 and 3.4 illustrate that both precipitation and heavy rain days have exhibited increases from 1960-2002. The frequency and duration of floods also are accentuated by intensive human activities. Destruction of vegetation has led to soil erosion, and land reclamation and siltation have shrunk the lake areas, while construction of levees has caused silting up some riverbeds and valleys.

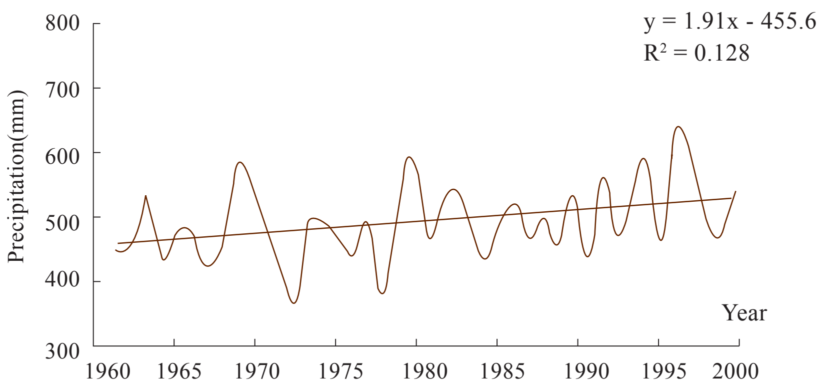

Fig. 3.3 Summer precipitation of Changjiang River (Su et al., 2005)

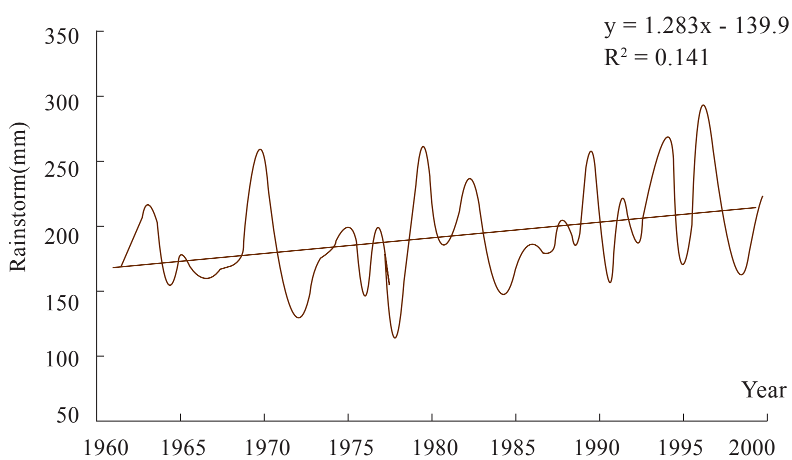

Fig. 3.4 Summer rainstorm magnitude of Changjiang River (Su et al., 2005)

Water shortages and increased water-related disasters not only influence agricultural production and affect development of secondary and tertiary industries, but also impact people's well-being in the sub-region. The sub-regional governments have made serious efforts to alleviate poverty and also improve their risk management capacity through such means as institutional strengthening, enforcement of law and policy implementation, etc.

3.2.2 Water Resources Development and Use

According to data from the 5 selected river basins, the cumulative water use is about 29.7 per cent of the global total water use, with the per capita water use being nearly 1.2 times the global average. Agriculture consumes about 60 per cent of total water use, with about 90 per cent being used for irrigation. As illustrated in Figure 3.5, the Northeast China sub-region is the world's largest irrigation area. Further, irrigation is still "extensive" in the sub-region, with its efficiency being as low as 25 per cent. Thus, agricultural irrigation is the sector with both the largest water consumption and water wastage.

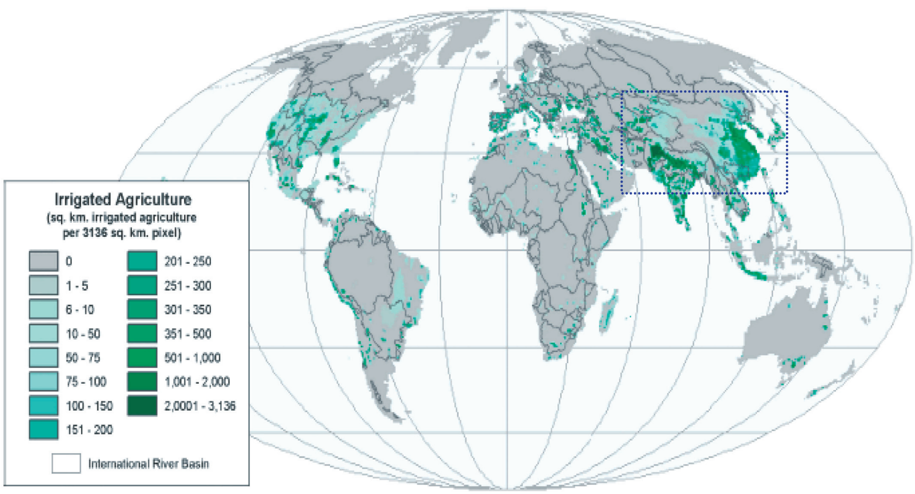

Fig. 3.5 Irrigated areas circa 1995 in Northeast Asia sub–region (blue dash rectangle) (UNEP, 2002A)

The Northeast Asia sub-region has a population density of 128.km^{-2}, with an urbanization rate of 42 per cent, thereby being one of the most populated areas in the world. As illustrated in Figure 3.6, the population density in 2002 has increased by 11.3 per cent, relative to that in 1990, with the urban population increasing by 41.5 per cent. Based on UNESCO estimates in 2002, the average per capita water use in developed countries was 500-800 L.day^{-1} (300 m^{3}.year^{-1}), compared to 60-150 L.day^{-1} (20m^{3}.year^{-1}) in developing countries. Thus, at the same time that the sub-region is experiencing improved economic and human well-being, the pressures on the available water resources are continuing to increase in this sub-region.

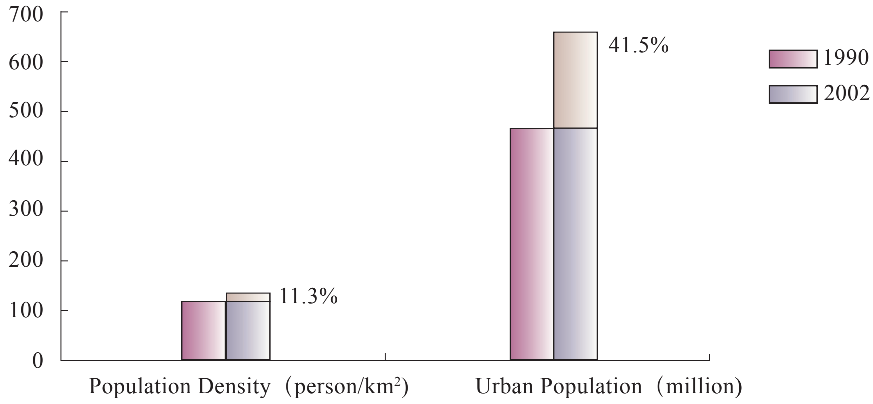

Fig. 3.6 Variation of population density and urban population in Northeast Asia sub–region (ADB, 2006)

Another sub-regional water issue is excessive groundwater mining that usually occurs in urban and concentrated industrial areas. The excessive mining activity in many cases has led to a lower groundwater table, surface subsidence, etc. The economic loss associated with surface subsidence in the Changjiang Delta region of the CRB has reached as high as 350 billion RMB.

Responses to over-exploitation of water resources in the sub-region are focused on alleviating water pressures (i.e., agricultural land use problems). The Chinese government, for instance, has launched several national key projects to adjust land use structure, with a typical project being the nationwide *Agricultural Land Conversion Project*, which attempts to convert all steep slope farmland to forests (grasses), as a means of restoring the degraded land use system.

Because of deteriorating water quantity and quality, a large proportion of the population in the Northeast Asia sub-region does not have access to IDWS, accounting for about one-third of the global total. Up to 2002, although 93.7 per cent of the urban population had access to IDWS, continued water pollution has significantly increased both water treatment costs and prices. The situation is even worse in the rural areas, with only 70.1 per cent of the rural population having access to IDWS up to 2002. More than half the livestock do not have sufficient drinking water (ADB, 2006). Further, there is a high contamination (i.e., concentrations above normal standards) of iodine, fluorine, arsenic, etc. in natural waters, especially in groundwater, the latter also being the threat to IDWS in rural areas.

The 5 selected rivers face two different pressures, in terms of IDWS. In urban areas, water pollution puts high pressures on the centralized water supply, with regard to high sewage emissions and a low efficiency of wastewater treatment. With the HRB as an example, the total wastewater discharge in 2000 was 4.267 billion m^3, almost twice that in 1980, resulting in 70 per cent of the drinking water supply source being badly polluted (i.e., being in Class V or worse). Poor water supply infrastructure and community service facilities in the rural areas continue to seriously constrain attainment of a safe water supply.

3.2.3 Water Resources for Ecological Health

The lakes and wetlands in the 5 selected river basins have been significantly degraded over the past decades. Based on investigations in Mongolia in 2003, 12.3 per cent of the lakes and 31.5 per cent of the springs were reported to have dried up in the ORB (Figure 3.7). Compared to remote sensing data from the 1950s, the wetland areas in the SHJRB of the SLB have been dramatically reduced to 26.1 thousand km^2 (10,077 mi^2) in 2000 (Figure 3.8).

In most of the Northeast Asia sub-region, economic development was initially the first priority in local government agendas. When the economic reform policy in China was implemented in 1980s, and the market economy in Mongolia was transited in 1990s, however, the water demands increased dramatically. Because of over-exploitation of water resources, land degradation and soil erosion are continuing to worsen. There are over 70 gold mining companies in the ORB, for example, that still work on strip burden, dumping pilings, and changing river flows. Soil erosion yields 1.6 trillion kg (1.6 billion tons) of sediment per year in the HRB. Further, the temperature is continuing to increase, while the precipitation is decreasing in recent years, as the climate changes to dryness, with the result being that the ecological health of water bodies has continued to deteriorate in the sub-region.

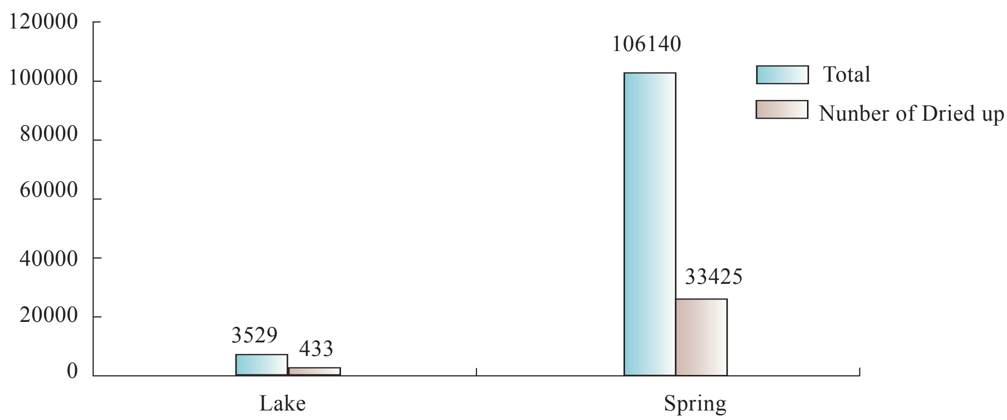

Fig. 3.7 Quantity variation of lake and springs in the ORB

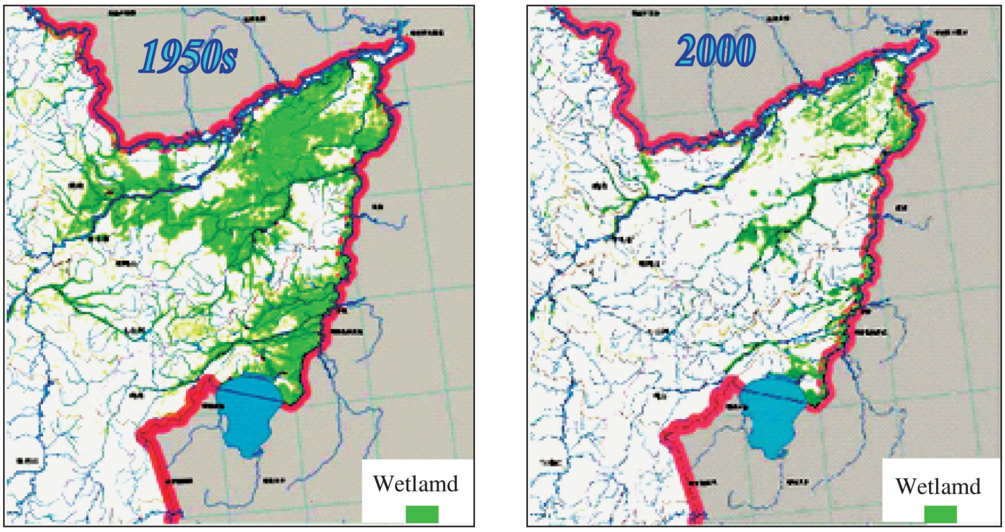

Fig. 3.8 Distribution changes of wetland in the SHJRB of the SLB

In addition to the shrinking of lakes and wetlands, the habitats of vegetation and animals are gradually being degraded, resulting in loss of biodiversity in the sub-region. Many endemic and endangered species (e.g., fish, amphibians, waterfowl, and aquatic mammals) are threatened with extinction. The population of the Yangtze River dolphin (*Lipotes vexillifer Miller*), for example, a well-known aquatic mammal that only exists in the CRB, rapidly declined to less than 100 individuals by 1995 (Figure 3.9).

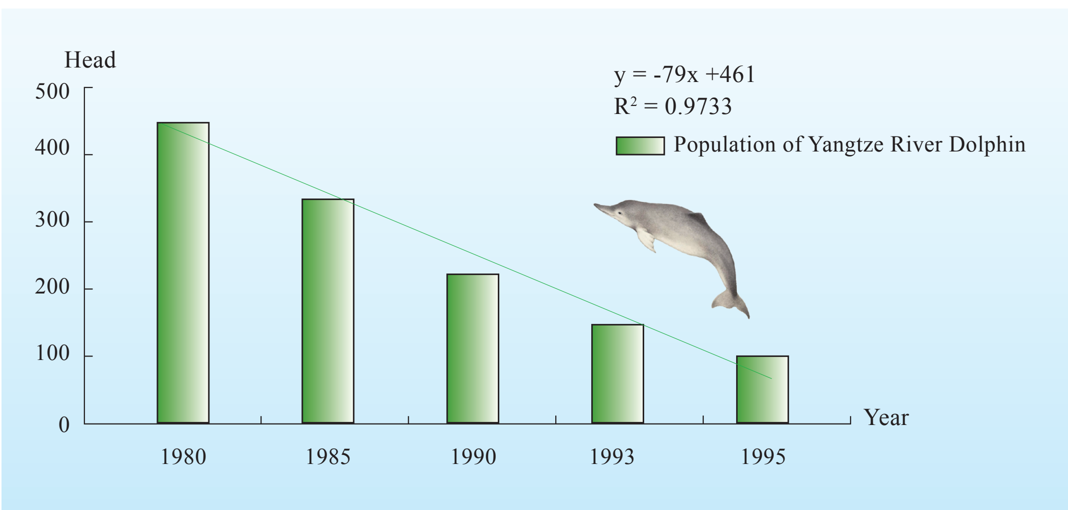

Fig. 3.9 Population variation of Yangtze River dolphin (Lipotes vexillifer Miller)

The water quality has generally deteriorated throughout the Northeast Asia sub-region. In Mongolia, animal husbandry is the key industry, with only a small level of industrial pollution. As a result, most water quality remains in the Class I and II categories. Recent mining activities, however, in addition to increased water consumption, have polluted the water resources. In the lower reaches of the TRB, the water quality has degraded to Class V. The main pollution source in China is wastewater discharges, with an estimated several billion tons of wastewater being discharged directly into the river (Figure 3.10).

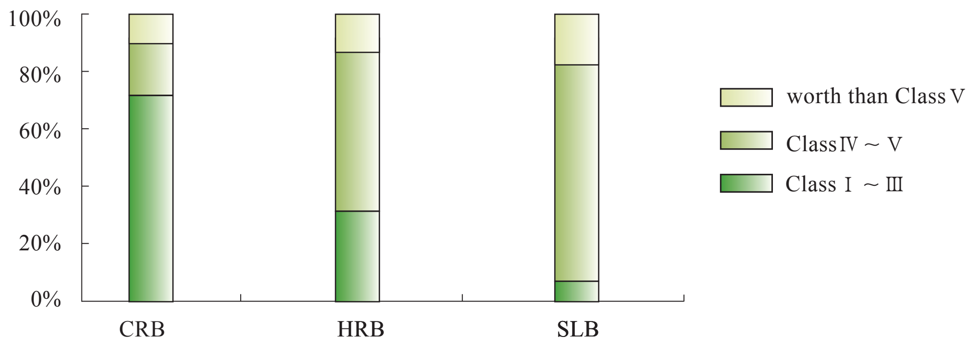

Fig. 3.10 Category of water quality in the CRB, HRB, and SLB (2003) (GOVCN−G)

Water pollution pressures arise from the following factors: (1) population increase; (2) rapid economic development; (3) improper industry structure; and (4) small investments in wastewater and sewage disposal equipment. Industrial development is based on increasing corporations with low technology requirements and high resource and energy costs. Small-scale manufacturing industries that can cause severe pollution (e.g., paper, chemical preparation, food processing, metal processing, leather processing, printing, and glass production) are rapidly increasing on a daily basis. These industries are not adequately treating the vast quantities of wastewater and sewage they produce.

Water pollution has exacerbated the water scarcity situation from bad to worse, severely affecting agricultural, industrial and domestic water supply, harming both human health and aquatic biodiversity. Further, water pollution has aggravated economic losses while restricting sustainable circulation among the economy, society, and the ecological environment.

The sub-regional governments are making efforts toward improving water quality. Key projects in China, for example, have been programmed in the 11th *Five Year Plan* on environmental prevention and control, identifying some crucial areas, including the upper reaches of the Changjiang, Huanghe, and Songhuajiang Rivers, and the Three Gorges Dam areas. At the same time, these projects also emphasize water sources and transit regions along the route of project *South-to-North Water Transfer*.

3.2.4 Water Resources Management

The WUGDP, an indicator of water use efficiency, generally reflects governmental achievements in water savings and environment protection. According to data from the 5 selected river basins, the average water use per unit GDP in the sub-region is only about 35 per cent of the global average, being among the lowest water use efficiency areas. Extensive irrigation, for example, has resulted in a loss of 75 per cent of the water in the agricultural sector. A key factor causing low water use efficiency in the industrial sector is a low input to infrastructure for improving water use efficiency.

Water resources have long been regarded as a “free resource,” with poor awareness on the value of water resources for overall economic development being reflected in the water resources management policy at different levels. Because of the lack of an appropriate valuation mechanism at the policy level, water resource use cannot be effectively controlled under the current policy framework. Thus, the price of water resources can not be effectively determined, usually being seriously underestimated. Driven by underestimated values, direct pressures on water resources arise as a result of low inputs for water-saving devices and technological development on the part of all water stakeholders, including both government and enterprises.

The problems related to water scarcity and water pollution are getting increasingly acute because of low water use efficiency. As previously mentioned, about 70 per cent of the water withdrawn for human use is lost during its transportation. Thus, increased investments in safe water facilities and water use management techniques are needed to significantly improve management of water use efficiency.

The major response directed to low water use efficiency in China comes in two levels. Firstly, under the general guidance of the central government’s new development strategy, policies on water resources conservation and improving water use efficiency have assumed a high priority. Secondly, the R&D input is rapidly increasing in the water sector. During the period of 2000-2005, an independent R&D project *Mmodernized Agriculture Water-saving Technology System and New Products* was implemented in research institutes, thereby greatly improving water use efficiency in irrigation.

Because of such factors as water scarcity and water pollution, the large population in the Northeast Asia sub-region does not have adequate access to improved sanitation (IS), being nearly 2.3 times more than that accessible to IDWS, and living in conditions posing high risks to their personal and environmental health. As of 2002, 62.3 per cent of the urban population has access to IS, in contrast to the poorer situation in the rural areas, the latter being only 32.5 per cent being served. Compared to the situation in 1990, however, about 200 million rural people have benefited from IS.

The availability of hygienic toilets is vital not only to protect drinking water, but also to ensure safe sanitation. Construction of hygienic toilets depends on tap water service systems (TWSS), and during the 1995-2005 period, the coverage of TWSS in the rural areas of the CRB increased steadily from 46.3 to 65.3 percent. Almost half of the population, however, still lacks access to adequate TWSS and sanitation infrastructures in the Northeast Asia sub-region (MH of PRC, 1996-2006).

4 Vulnerability Index and Conclusions

As an important component of the vulnerability assessment of freshwater resources, an integrated VIS was developed to demonstrate the general states of river basins, based on the major factors considered in this assessment exercise. A detailed description of the VIS is given in the methodological guidelines (Huang & Cai, 2008).

Table 4.1 summarizes the VI of the 5 selected river basins in the Northeast Asia sub-region. Based on the methodological guidelines, the general VI and its indicators are delineated by colors into 4 grades of vulnerability, including low, moderate, high, and severe.

Table 4.1 Vulnerability Indexes of 5 selected river basins in Northeast Asia sub−region

	RSs	RSv	DPs	DPd	EHp	EHe	MCe	MCs	MCc	VI
CRB	0.000	0.225	0.195	0.145	0.174	0.395	0.929	0.145	0.400	0.264
	0.113		0.169		0.286		0.491			
SLB	0.128	0.740	0.330	0.182	0.231	0.370	0.937	0.229	0.290	0.369
	0.434		0.256		0.300		0.486			
HRB	0.684	0.347	0.656	0.250	0.680	0.520	0.995	0.250	0.400	0.529
	0.516		0.453		0.600		0.548			
TRB	0.255	0.554	0.041	0.379	0.420	0.829	0.657	0.574	0.340	0.441
	0.405		0.210		0.625		0.524			
ORB	0.000	0.515	0.022	0.827	0.073	0.073	0.956	0.952	0.420	0.383
	0.257		0.428		0.073		0.776			

Low	Moderate	High	Severe

The following conclusions can be synthesized from the results in Table 4.1, as follows:

[1] The vulnerability grades of the five selected river basins generally range from moderate to high, and management-related interventions are urgently needed to improve the state of water resources in the region.

[2] Except for the CRB (located in the humid and semi-humid areas) and the ORB (with very low population density), the remaining river basins in the sub-region generally exhibit water resources problems. Their basins are relatively dry, and exhibit a low per capita availability of water resources. In addition to water scarcity, they also suffer from unstable annual water resources recharge capacity. As an example, the SLB experiences serious water shortages related to large inter-annual variability in precipitation that increase the constraints to adopting sustainable water resources management plans practices.

[3] In regard to water resources development and use, the water resources exploitation rate is usually high in the river basins suffering from water shortages. This is clearly demonstrated with the HRB analysis, which identified a water resources exploitation rate as high as 65 per cent. Further, although the other river basins don't exhibit a critical designation, the continuous population increase and urban expansion occurring in them require a continually-increasing water supply, thereby also presenting future water resources development and use challenges. Further, over-exploitation of both surface and groundwater resources will negatively impact the healthy hydrological processes, subjecting the river basin to high ecological risks.

[4] In terms of ecological health, most of the river basins are at risk, including those currently exhibiting a low vulnerability, mainly because of the continuous deterioration of water quality in the sub-region, and the increasing recognized problematic development trends, based on the available data. This conclusion also is supported by another indicator; namely, vegetation coverage (including wetland). The vegetation coverage is relatively low in all 5 selected river basins, further contributing to increased limitations in regard to eco-rehabilitation.

[5] There is a high disparity in management capacity among the 5 selected river basins, with the common problem being poor water use efficiency. Although most of the river basins exhibit a scarce water supply, due to various factors affecting management capacity (both technical and policy in nature), water use efficiency remains very low.

[6] Conflict management is another important indicator for those countries in the Northeast Asia sub-region with transboundary river basins. Although they are not all international rivers, the 5 selected river basins are large in area, and exhibit various levels of transboundary management issues. The management of the 3 selected river basins in China, for example, is similar in regard to institutional arrangements, but still exhibit minor variations in terms of management capacity. The situation is similar for the 2 selected Mongolian river basins.

Based on the above synthesis, the following policy recommendations should be considered for improving water resources management in the Northeast Asia sub-region in the future:

[1] Improved water use efficiency – Although the 5 selected river basins are located mostly in

arid and semi-arid zones, and characterized by scarce water resources, the water use efficiency remains very low. The key factors contributing to water use efficiency are development policy and technical input. Water use is still dominated by the agricultural sector in the Northeast Asia sub-region, with water use efficiency in agricultural sector being relatively low, compared to other sectors. Thus, the development policy in the agricultural sector must be re-assessed, and relevant policies formulated to improve water use efficiency in this sector, including: (1) refinements in the structure of agricultural production; and (2) introduction of economical incentives in water-pricing policies. Improved water use efficiency also will require strong technical support (development of water-saving technologies in agriculture and other industries). The R&D activities for water resources management in the Northeast Asia sub-region are relatively low, and should be included in the priorities of the technological development agenda of the countries of the sub-region.

[2] Comprehensive river basin management – The current water resources management scheme is based on a political administrative system that is weak in regard to enhancing coordination between different reaches of the various river basins. Different reaches of the river basins have unique characteristics, and play different roles in the whole river basin ecosystems. The current centralized management system leaves little opportunity for cross-basin coordination. Thus, basin-wide management institutions must be further strengthened through decentralization and proactive involvement of local governments. At the same time, the participation of all water stakeholders, as a key to successful river basin management, also must be encouraged. Another important aspect of basin-wide management is ensuring rational water resources use through a coordinated mechanism for water resources allocations.

[3] Environmental protection and pollution control – Except for the ORB, which exhibits a better ecological condition in regard to both pollution and vegetation, the remaining 4 river basins analysed in this study are under severe threats of environmental degradation. Thus, protecting the environment will be very important for restoring the degraded ecosystems. Relevant measures may include erosion and sedimentation control, sufficient ecological flows, and pollution control through controlled pollutant discharges.

[4] Poverty alleviation and safe drinking water – Poverty alleviation will remain an important development task of integrated river basin management for a long time. Management priorities must be established to meet the basic needs of the poor population, including safe drinking water supply, establishment of alternative livelihoods, and building the capacity of local people to solve their problems through participatory resources management activities.

References

- ADB (Asian Development Bank), 2006. Asia Water Watch 2015 – Are countries in Asia on Track to Meet Target 10 of the Millennium Development Goals?
- Baldandorj, T., 2005. Water management for Mongolia.
- Chandmani, D., 2005. Water amelioration, 101—103.
- Che, Z.X., Wang, Q.Z., 2002. Cause and Countermeasure of the Huanghe River Cut-off. Journal of Shandong Meteorology, 04: 11—13.
- Davaa, G., Myagmarjav, B., 1975, 1999. Surface Water of Mongolia, 1.13—1.35, 9.1—9.15.
- FAO-SDRN-Agrometeorology Group, 1997. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/atmospheric_moisture/geographic_patterns_equator_subtropics.html.
- Huang, Y., Cai, M.T., 2008. Methodological Guidelines for Vulnerability of Freshwater Resourus to Environmental Change in Asia ISBN:978-92-807-2953-5, Job Number: DEW/1106/BA.
- IMF (International Monetary Fund) http://www.imf.org/external/pubs/ft/weo/2007/01/data/index.aspx.
- MFA of PRC (Ministry of Foreign Affairs of People's Republic of China):
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1221/1221x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1236/1236x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1261/1261x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1281/1281x0/default.htm.
- MH of PRC (Ministry of Health of People's Republic of China), Statistics Yearbook Abstract 1996-2006.
  http://www.moh.gov.cn/menunews/C30302.htm.
- MSY (Mongolian Statistics Yearbook), 2005, 2006.
- CSY (China Statistics Yearbook), 2006. National Bureau of Statistics of China. http://www.stats.gov.cn/tjsj/ndsj.
- Scientific Survey Reports of Orkhon and Tuul River Basin. 2005, 2006.
- Statistic Book of Nature and Environment, 2000.
- Su, B.D., Jiang, T., Jin, W.B., 2006. Recent trends in observed temperature and precipitation extremes in the Yangtze /river basin, China. Theor Appl Climatol, 83: 139—151.
- GOVCN (Central People's Government of People's Republic of China):
  A: http://www.gov.cn/test/2005-08/11/content_27116.htm;
  B: http://www.gov.cn/test/2005-07/27/content_17402.htm;
  C: http://www.gov.cn/test/2005-06/24/content_17362.htm;
  D: http://www.gov.cn/test/2005-07/27/content_17405.htm;
  E: http://www.gov.cn/test/2006-04/04/content_244533.htm;
  F: http://www.gov.cn/test/2005-07/27/content_17403.htm;
  G: http://www.gov.cn/test/2005-07/27/content_17758.htm.

- UNEP, 2002A. Atlas of International Freshwater Agreements. http://www.transboundarywaters.orst.edu.
- UNEP, 2002B. Vital Water Graphics – An Overview of the State of the World's Fresh and Marine Waters.
- WB (World Bank) http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html.
- Xinhuanet:
  http://news.xinhuanet.com/ziliao/2002-04/01/content_329931.htm;
  http://news.xinhuanet.com/ziliao/2002-06/13/content_438328.htm;
  http://news.xinhuanet.com/ziliao/2002-06/18/content_445580.htm;
  http://news.xinhuanet.com/ziliao/2002-06/18/content_445618.htm;
  http://news.xinhuanet.com/ziliao/2002-07/04/content_469910.htm.
- Zhao, S.J., Fang, S., Miao, B., Gu, S., Tao, C., Peng, Z., 2004. The seven-decade degradation of a large freshwater lake in central Yangtze River, China. Environmental Science and Technology, 39: 431—436.

Glossary

- Access: Access refers to the rights or entitlements of an individual or a group to obtain or make use of water resources or the services that water provide for different uses.

- Actual renewable water resources: The maximum theoretical amount of water actually available for use in a basin or country, including both internal renewable resources and external renewable resources. This takes into consideration the quantity of water reserved for upstream and downstream basins or countries through formal or informal agreements or treaties, and possible reduction of external water due to upstream water withdrawals.

- Adaptation: A process of societies and ecosystems dealing with water stresses, and referring to the capacity of societies and ecosystems to handle their water resources vulnerability issues.

- Conflict management capacity parameter: A parameter demonstrating the capacity of river basin management system to deal with transboundary conflicts. A good management system can be assessed by its effectiveness in institutional arrangements, policy formulations communication mechanisms, and implementation efficiency.

- Domestic uses of water: Drinking water plus water withdrawn for homes, municipalities, commercial establishments, and public services (e.g., hospitals).

- Ecological health: The ecosystem health of a river basin. Low wastewater discharges and high vegetation cover on the land surface generally reflect a good ecological health of a river basin.

- Ecological water use: All ecosystems require water to maintain their ecological processes and associated communities of plants and animals. Environmental water requirements describe water regimes needed to sustain the ecological values of water-dependent ecosystems at a low level of risk.

- Ecosystem deterioration parameter: The land ratio without vegetation coverage (forest area and wetland) used to present the contribution of an ecosystem's deterioration to the vulnerability of its water resources.

- Freshwater: The portion of water resources suitable for use by humans and most terrestrial vegetation and wildlife. It is renewable from rainfall, in the form of runoff to surface water, groundwater and water retention by soil. In this report "water" and "freshwater" are used synonymously.

- Groundwater recharge: The total volume of water entering aquifers within a basin or country's borders from endogenous precipitation and surface water flows.

- Improved sanitation: Facilities that hygienically separate human excreta from human, animal and insect contact, and include sewers and septic tanks, poor- flush latrine and simple pits, etc.

- Improved sanitation accessibility parameter: A parameter typically used to measure the capacity of a management system capacity to deal with the livelihood needs of inhabitants, and refers to the percentage of population with sustainable access to improved sanitation facilities.

- Improved water supply/source: These sources include piped water, public taps, boreholes or pumps, protected wells, or protected springs or rainwater.

- Indicator: A parameter, or value derived from parameters, which points to, or provides information about, the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value.

- Industrial uses of water: Includes cooling machinery and equipment, production of energy, cleaning and washing goods produced as ingredients in manufactured items and as a solvent.

- Internal renewable water resources: The average annual flow of rivers, and the recharge of groundwater (aquifers), generated from precipitation occurring within a basin or country's borders.

- Irrigation water use: The primary water use in the agricultural sector.

- Management capacity: The capacity of a management system to cope with mismatches between water resources demands and water supply, by improving water use efficiency (measured by WUGDP) and human health conditions (measured by access to adequate sanitation facilities).

- Policy: A plan of action to guide decisions and actions. The term may apply to governments, private sector organizations and groups, and individuals. The policy process includes identification of different alternatives (e.g., programs and spending priorities), and choosing among them on the basis of their potential impacts. Overall, policies can be understood as political, management, financial, and administrative mechanisms arranged to reach explicit goals. Policy alignment is the process by which consistency is achieved across a number of policies that have the potential of interfering with each other.

- Safe drinking water accessibility parameter: Designed to present the state of social adaptation of freshwater use (i.e., how freshwater resources development facilities address the fundamental livelihood needs of the population). This is an integrated parameter reflecting a comprehensive impact of the coping capacity of all stakeholders.

- Sectoral water withdrawals: The proportion of water resources used for one of three major purposes: agriculture, industry, and domestic uses. All water withdrawals are allocated to one of these three categories.

- State: The state or status of a water system, as described by adequate structural (river morphology), physical (temperature), chemical (concentration of phosphorus and nitrogen), and biological (abundance of phytoplankton or fish) indicators.

- Surface Water: Water on the Earth's surface, such as in streams, rivers, lakes, or reservoirs. It includes the average annual flow of rivers generated from endogenous precipitation (precipitation occurring within a basin or country's borders). Surface water resources are usually computed by measuring or assessing the total river flow occurring in a country or a river basin on an annual basis.

- Total water resources: The total freshwater available in a river basin to maintain healthy ecosystems and socioeconomic development.

- Transboundary management: The framework for managing water resources across a basin and beyond political borders, including management for resolving water use conflicts.

- Vulnerability: The characteristics of a water resource system's weaknesses and flaws that make the system difficult to function in the face of socioeconomic and environmental changes.

- Vulnerability assessment: An investigation and analytical process to evaluate a system' s sensibility to potential threats, and to identify key challenges to the system in reducing or mitigating the risks of negative consequences from adversarial actions.

- Water resources management: Planned development, distribution and use of water resources, in accordance with predetermined objectives, and with respect to both the quantity and quality of these resources.

- Water pollution parameter: A parameter for measuring the ecological health of the river basin, defined as the ratio between the untreated wastewater discharges and the total water resources in a river basin.

- Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

- Water scarcity: A relative concept, describing the relationship between water demands and water availability. The demand may vary considerably between different countries, and different regions, within a given country or basin, depending on sectoral water uses. Thus, a country or basin with high industrial water demand, or which depend on large-scale irrigation, will be more likely to exhibit more water scarcity than a country or a basin with similar climatic conditions, but which lack such demands.

- Water scarcity parameter: The richness of the water resources in a given basin will dictate the degree to which the water demands of the population can be met. Thus, the scarcity of water resources can be expressed as the per capita water resources of a region (country or basin), compared to the generally accepted minimum level of annual per capita water resource requirement (1,700 $m^3.person^{-1}$).

- Water stress parameter: Water stress causes deterioration of freshwater resources, in terms of quantity (over-exploitation of aquifers and dry rivers) and quality (eutrophication, organic matter pollution, and saline intrusion). The water stress parameter refers to the ratio of total water withdrawals to the total water resources available in a river basin.

- Water use: The total quantity of water distributed to all different water users (including losses during its transportation to its point of usage). Based on the intended purposes, water use can be divided into productive (agricultural or industrial) water consumption; domestic water consumption; and ecological or environmental water consumption. Water use refers to human interactions with, and influence on, the natural hydrologic cycle, and includes elements such as water withdrawals from surface and groundwater sources; water delivery to homes and businesses; consumptive water uses; water released from wastewater treatment plants; water returned to the environment; and in-stream water uses (e.g., water for producing hydroelectric power).

- Water use efficiency: The GDP produced from the use of one cubic meter of water, i.e., WUGDP.

- Water use inefficiency parameter: A parameter representing the inefficiency of a water resources management system, as demonstrated by the gap between a basin or country's water use efficiency and the average water use of selected countries as a standard of comparison. In this report, the water use inefficiency parameter is presented as the gap between the GDP value from one cubic metre of water use in a basin, compared to the average GDP value produced from one cubic metre of water use in the world's top food producers (China, USA, Mexico, Brazil, and France).

- Water variation parameter: The variation of the water resource, expressed as the coefficient of variation of annual precipitation over the last 50 years.

- Water withdrawals: The gross quantity of water extracted from any source, either permanently or temporarily, for a given use. It can be either diverted to a distribution network or used directly. The term includes consumptive water uses, conveyance losses, and return flows. The total water withdrawal is the sum of the estimated water uses by the agricultural, domestic and industrial sectors.

淡水资源危机

东北亚

环境变化下的淡水资源脆弱性评估

长江流域

黄河流域

鄂尔浑河流域

松辽流域

土拉河流域

黄 艺

蔡满堂

张金华

达巴巴扎尔·詹德马尼

蔡佳亮

UNEP 联合国环境规划署

北京大学·中国

УСНЫ ХЭРЭГ ЭРХЛЭХ ГАЗАР 蒙古水利部

ISBN：978-92-807-2948-1
联合国环境规划署工作编号：DEW/1101/BA

联合国环境规划署
地址：肯尼亚内罗毕邮政信箱30552
电话：(+254) 20 7621234
传真：(+254) 20 7623927
网址：http://www.unep.org

封面照片贡献
背景：Tom Murphy / WWI / Still Pictures
左/中/右：蔡满堂

免责声明

本出版物阐述的观点不一定是本项目所有合作机构的观点。本出版物中使用的名称或其表述不意味着联合国环境规划署或其合作机构对于任何国家、领土、城市或其政府的合法地位，或对于其边界或者疆界的划分表示任何意见。

本出版物中提及的公司或产品不意味着其受到联合国环境规划署的认可。不得将本出版物中的专利产品的信息用于广告宣传。本出版物中对所使用的商标名称和符号的美术编辑不意味着对该商标或版权的侵权。

我们对本书内容中可能存在的错误或疏漏深表歉意。

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on 100% recycled paper using vegetable based inks and other eco-friendly practices. Our distribution policy aims to reduce UNEP’s carbon footprint.

致谢

本项目得到了联合国环境规划署（UNEP）的大力支持，由比利时政府的比利时发展合作计划提供经费资助。特别感谢UNEP的张金华、Salif Diop和Patrick M' mayi在项目全过程中的所给予协助和指导。

本项目是由北京大学（PKU）和蒙古水利部水资源研究所（MWA）共同合作完成的。参与人员包括：黄艺、蔡满堂、Dambabazar Chandmani、蔡佳亮、Sanduijav Narantuy、赵曦、费颖恒、晁元卿、敖小兰、彭博、Yadamtsoo Tsedenbaljir、杨青、礼晓和郑维爽等。

同时感谢为本项目报告提供宝贵资料和建设性意见的专家。他（她）们分别是郑炳辉、葛查忠、张远航、唐孝炎、郭怀成、Dagva-Ochir Saikhanjargal、Mukand Babel、温东辉、吴为中、谢曙光、黄志基、殷贺和周丰等。

也感谢在数据搜集中提供大量帮助的机构，包括：中国环境科学院、中国水利部、中国国家统计局、蒙古国家统计局、中国外交部、中国卫生部，以及其他大学与科研机构。

本项目报告中的图表摘自其他机构出版物，其来源在文中的适当部分详细说明，同时列入参考文献中。

前言

淡水资源对地球上的生命来说，是必不可少的。目前，千年发展目标（MDGs）的实现正受到越来越多来自社会、经济和环境方面的压力，其中包括人口膨胀、过度开发土地资源、污染加剧、气候变化以及不可持续发展的管理手段等。水资源综合管理（IWRM）已被公认为是人类社会应对这些挑战最优先实施的事项之一。这对于水资源普遍匮乏的亚洲地区国家而言，具有尤为重要的意义。因此，如何更好地理解环境变化下的水资源脆弱性，对其知情决策是至关重要的。

本出版物是联合国环境规划署（UNEP）、北京大学以及蒙古水利部水资源研究所（MWA）共同合作完成的成果，主要对东北亚地区的淡水资源作了综合脆弱性评估。本项评估选取了地区内5个具有代表性的流域，即中国境内的长江流域（CRB）、黄河流域（HRB）和松辽流域（SLB），以及蒙古境内的Orkhon河流域（ORB）和Tuul河流域（TRB）。流域总面积近400万 km^2，流域总人口超过10亿。自1995年以来，东北亚地区已约有3.5亿人受益于千年发展目标而得到改善的饮用水供应，但目前仍有超过7亿人无法得到改善的饮用水供应和卫生设施。

基于5个所选流域大量的科学依据和数据，本项评估报告还证实了气候变化与水资源的可获得性之间具有显著的相关关系，即全球气候变暖将进一步影响这些流域的水平衡，并且加剧旱灾和水灾的发生频率和强度。

然而，面对这些挑战，目前还没有通用的解决方案。因此，迫切需要创新的流域政策干预，来减缓这些流域水资源脆弱性所受环境变化的影响，为其今后的可持续发展提供最优保障。在这里，我们希望本项评估报告能够作为一个有用的资源，供中国和蒙古两国水资源综合管理方面的决策者参考，同时，也希望能够有助于其他利益相关者更好地理解东北亚地区水资源综合管理的重要性和紧迫性。本出版物另附一张电子光盘，供读者获取更多有关东北亚地区流域及其子流域的水资源信息。

Achim Steiner

联合国副秘书长兼联合国环境规划署执行主任

阿奇姆•施泰纳（Achim Steiner）

2008年10月

缩 略 词 表

缩写	全称	缩写	全称
ADB	亚洲发展银行	MSY	蒙古统计年鉴
CRB	长江流域	ORB	Orkhon河流域
CSY	中国统计年鉴	P.R. China	中华人民共和国
DP	发展压力	R. Korea	大韩民国
D.P.R. Korea	朝鲜民主主义人民共和国	R&D	研究与开发
EH	生态健康	RB	流域
FAO	联合国粮农组织	RS	资源压力
GDP	国内生产总值	SHJRB	松花江流域
GIS	地理信息系统	SLB	松辽流域
GOVCN	中华人民共和国中央人民政府	TRB	Tuul河流域
HRB	黄河流域	TWSS	自来水供水系统
IDWS	改善饮用水供水系统	UNEP	联合国环境规划署
IMF	国际货币基金组织	UNESCO	联合国教科文组织
IS	改善卫生条件	US	美国
LRB	辽河流域	US$	美元
MC	管理挑战	VI	脆弱性指标
MDGs	千年发展目标	VIS	脆弱性指标系统
MFA	中华人民共和国外交部	WB	世界银行
MH	中华人民共和国卫生部	WUGDP	单位GDP用水量

单 位：

°C	摄氏度
km	千米
km^2	平方千米
km^3	立方千米
kw	千瓦
mm	毫米

目录

表目录索引

图目录索引

摘 要

引言

水资源通常被定义为能被人类使用的水的总体。随着人口数量的激增和社会经济的发展，人类对水资源的需求日益俱增。与此同时，急速膨胀的人类活动已经对淡水生态系统的健康造成了巨大的负面影响，最直接的表征就是淡水资源的脆弱性凸现。因此，合理的水资源管理已成为世界走向可持续发展所面临的主要挑战之一，还被纳入各国的可持续发展议程之中。在气候和社会经济变化的背景下，发起水资源脆弱性评估，无疑将能帮助相关方面更好地进行决策。

总的来说，该研究分为两个步骤，即：①对本地区的水资源现状作一个概况分析；②在本地区选择5个具有代表性的重要流域，从淡水资源现状，导致现状脆弱性的驱动力和压力，由现状带来的影响，以及消除流域尺度主要威胁的响应等5个方面，对其分布作一个综合分析。考虑到水资源管理的本质，该研究建立在检验四个主要成份的概念框架上：①水资源形成的天然水文学过程；②用于人类福利和社会经济发展的水资源开发与利用；③水资源维持流域系统健康的生态/环境功能；④管理能力。

作为联合国环境署（UNEP）所组织开展的“气候变化下全球淡水资源脆弱性评估”的一部分，本报告包括：①地区概况和地区内所有国家影响淡水资源的主要因素；②基于5个被选流域案例的研究结果，进行深入的淡水资源脆弱性评估分析；③附件：5个选定流域案例研究报告全文。

地区概况

东北亚地区幅员辽阔，陆地总面积为11,764,596 km^2，约占世界的1/12；濒临太平洋，海岸线长86,199 km，拥有岛屿众约22,000个。东北亚地区由5个国家组成，分别为中华人民共和国、蒙古国、日本国、大韩民国和朝鲜民主主义共和国。东北亚地区地形复杂多样，拥有陆地上5种基本的地形类型，即高原、平原、盆地、山地和丘陵。其中，山地占54.6%，成为最主要的地形类型。东北亚地区普遍坡度陡峭、地势崎岖，自西向东形成三级阶梯，高度渐低。

由于多种多样的气温—降水组合，东北亚地区同时拥有大陆性气候、海洋性气候和季风气候等3种气候类型。根据年度积温（日平均气温连续≥10℃的累加气温）分布，可将东北亚地区划分为5个温度带，即热带、亚热带、暖温带、中温带和寒温带。

在东北亚地区，占世界陆地总面积1/12的土地上生活着占世界1/4的人口，人均土地面积仅为0.0078 km^2，是世界平均水平的1/3。耕地面积1,390,046 km^2（11.82%），森林面积为2,305,080 km^2（19.59%），牧场面积为4,285,510 km^2（36.42%），以及其他面积为2,732,876 km^2（23.23%）。因此，东北亚地区耕地资源十分匮乏。

东北亚地区动植物种类丰富，分布错综复杂，是世界上生物资源最丰富的地区之一。据报道，地区内目前已探明储量的矿产资源种类均值约为170种。其中，钨、锑、稀土、钼、钒和钛等储量居世界首位，煤、铁、铅、锌、铜、银、汞、锡、镍、磷灰石、石棉、石墨和菱镁矿储量居世界前列。

东北亚地区总人口约为1,508,263,000，约占世界的1/4，人口密度约为128人/km^2，属于世界上人口最为稠密的地区之一。根据近5年来的统计数据，东北亚地区年均人口自然增长率为9.36‰，与20世纪80、90年代相比，增长率持续呈现减少的变化趋势。与此同时，老龄化率却在逐年递增。

2006年，东北亚地区GDP增长率约为9.275%（除朝鲜），是世界预期增长率的约1.5倍，GDP总量约为76,343亿美元，人均GDP约为5,062美元，约为世界平均水平的62%。相关数据表明，地区经济发展正处于快速增长期，但与世界平均水平相比还有较大差距，地区内发达国家与发展中国家之间的经济实力也仍相差悬殊。

淡水资源概况

受地理位置、地形地貌、气候等多种自然因素的综合影响，东北亚地区水资源特征主要表现为以下5个方面：(1) 河流流程较长，(2) 流域面积较广，(3) 水势落差较大，(4) 国际流域分布较多，(5) 各国间差异显著。

除朝鲜外，东北亚地区水资源总量约为3,351 km^3，约占世界的1/300；人均水资源量约为2,221 m^3，约为世界平均水平的25.7%。由此表明，东北亚地区在水资源总量和人均水资源量上都是最为贫乏的地区之一。

东北亚地区是世界上降水量较丰富的地区之一，年均降水量约为1,100 mm，空间分布呈现出由西向东、由北向南降水量逐渐增多的变化规律。根据等降水量线值，湿润和半湿润地区约占东北亚陆地总面积的约54%，而干旱和半干旱地区则约占46%。东北亚地区雨季时季风活动频繁，降水量占了全年的70～80%；旱季时，则主要依靠地下水、冰雪融水和水库蓄水的补给。根据近200年来洪涝和干旱灾害频度分析，东北亚地区每50年洪灾和旱灾的发生比例都呈增长的趋势，其中旱灾比例增加最快，已达36%。这些证据都表明，东北亚地区淡水资源脆弱性正处于加剧恶化之中。

除朝鲜外，东北亚地区用水总量约为684.3 km^3，约占世界的29.7%，人均用水量约为454 m^3，约为世界的1.2倍。由此表明，东北亚地区是世界上用水紧张的地区之一。截至2002年，东北亚地区约有3.35亿人无法得到改善的饮用水供应，约占世界的1/3，形势十分严峻。但相比1990年，由于“千年发展目标”（MDGs）的执行，改善饮用水供应状态目前正在处于持续不断地快速增加之中。

随着围湖造田、过度灌溉和过度放牧等粗放型不可持续的生产方式的日益增长，湖泊生态系统面临巨大的压力，东北亚地区湖泊面积萎缩严重。同时，水质恶化已越发成为水资源保护中的一个棘手问题。

对一个水资源严重稀缺的地区来说，维持水资源供需平衡的关键措施之一就是提高水资源利用的效率。显而易见，水资源利用效率是一个包含众多变量的函数，其中包括技术、价格和知识等。单位GDP用水量，作为一个非常重要的价格指示标，能够较为真实而准确地反映各级政府在节约水资源和环境保护方面所作出的成绩。

截至2002年，东北亚地区约有7.51亿人无法使用上改善的卫生设施，其中农村地区占了大多数，约78.3%。但相比1990年，使用上改善的卫生设施的人口正在持续不断地快速增加之中。

在国际流域的管理中，涵盖了诸多交互作用的因素，诸如自然因素、行政因素和人文因素等，从而使得国家间共同分享水系的管理工作变得困难重重。为了解决现存的争端、避免潜在的冲突，20世纪以来国际社会始终致力于发展和完善国际流域管理的各项法则。

淡水资源脆弱性评估

基于上述东北亚地区淡水资源的综览，需要对该地区淡水资源的脆弱性作进一步的系统分析。在中国和蒙古两个团队参与者的共同努力下，对所选取的5个具有代表性的流域，即中国境内的长江流域（CRB）、黄河流域（HRB）、松辽流域（SLB）和蒙古境内的Orkhon河流域（ORB）、Tuul河流域（TRB），分别作了细致分析。导致地区淡水资源脆弱性的重要问题总结如下：

淡水资源和气候变化

虽然东北亚地区有着相对丰富的年均降水量，但水资源仍然十分脆弱。一方面，大多数流域属于大陆性气候，从而使得流域内降水量较少。另一方面，气候变化导致气温—降水的分布变化，从而大大增加了淡水资源的脆弱性。在半湿润、半干旱和干旱地区，降水量、地表径流量明显减少，同时变化速度却在增加，使得水资源变得越来越稀缺，一些河流甚至已经部分干涸。与此同时，在湿润地区，降水量和地表径流量则呈现增长的趋势，尤其是在最近的10年间，季风对降水量的影响十分显著，约有70～80%的降水集中分布在7～9月。因此，雨季的洪水暴发在这些地区已成为了一个大问题。

农业用水和饮用水

东北亚地区的农业灌溉大多为过度状态，且灌溉效率十分低，仅为25%。因此，农业灌溉不仅是最大的水消耗单元，也是最大的水浪费单元。受水质的影响，东北亚地区有较大比例的人口无法得到改善的饮用水供应。在城市地区，水污染对集中供水的污水排放和处理效率两方面都造成了巨大压力。

生态系统退化

随着湖泊和湿地的不断萎缩，动植物的栖息地正在逐渐消失，从而导致东北亚地区生物多样性的丧失。据统计，许多特有的濒危物种，像鱼类、两栖类、水禽、水生哺乳动物等正面临灭绝的威胁。

水污染

东北亚地区水质恶化非常普遍。水污染的压力来自以下几个方面：①人口膨胀，②迅猛的经济发展，③不合理的产业结构，④废水和污泥设备投资过少。水污染使水资源短缺的状态每况愈下，严重影响农业、工业和生活供水，对人体健康和水生生态系统的生物多样性造成损害。此外，水污染在加剧经济损失的同时，还制约了经济、社会和生态环境的可持续循环发展。东北亚地区的各级政府都在千方百计地改善水质。

用水效率

一般而言，单位GDP用水量，作为一个非常重要的价格指示标，能够较为真实而准确地反映各级政府在节约水资源和环境保护方面所作出的成绩。由于在政策层面上缺乏适当的估价机制，在现行的政策框架下，水资源利用不能得到有效地控制。因此，水资源价格无法得到合理地确定，并且通常还被严重低估。由于用水效率低下，水资源短缺和水污染的问题就变得日益尖锐，约70%水可能在运输途中损失。然而，增加节水设施和用水管理的投入将使水资源利用效率提高一倍。

脆弱指数

在深入分析的基础上，分别计算出每条河流的各脆弱性指数（见下表），结果总结如下。

（1）所选五个流域的脆弱性级别为“中度”或“高”两个级别，改善水资源状态急需水资源管理的介入；

（2）总体而言，除了长江流域属于湿润和半湿润地区，Orkhon河流域人口密度非常低外，其他流域在水资源基本状况上都存在较大问题，主要表现为干旱且人均水资源量较低。同时，这些流域还遭受年内水资源量不稳定交换的影响。例如，松辽流域，年均降水量的严重的分布不均加大了水资源可持续管理上的难度。

东北亚地区选定5个流域的脆弱性指数

Vulnerability Indexes of five selected river basins in Northeast Asia sub–region

<table>
<tr><th></th><th>水资源匮乏（RSs）</th><th>水资源变化（RSv）</th><th>水需求压力（DPs）</th><th>安全饮用水可获得性（DPd）</th><th>水污染（EHp）</th><th>生态退化（EHe）</th><th>用水效率（MCe）</th><th>改进的卫生设施（MCs）</th><th>管理能力（MCc）</th><th>脆弱性指数（VI）</th></tr>
<tr><td rowspan="2">CRB</td><td>0.000</td><td>0.225</td><td>0.195</td><td>0.145</td><td>0.174</td><td>0.395</td><td>0.929</td><td>0.145</td><td>0.400</td><td rowspan="2">0.264</td></tr>
<tr><td colspan="2">0.113</td><td colspan="2">0.169</td><td colspan="2">0.286</td><td colspan="3">0.491</td></tr>
<tr><td rowspan="2">SLB</td><td>0.128</td><td>0.740</td><td>0.330</td><td>0.182</td><td>0.231</td><td>0.370</td><td>0.937</td><td>0.229</td><td>0.290</td><td rowspan="2">0.369</td></tr>
<tr><td colspan="2">0.434</td><td colspan="2">0.256</td><td colspan="2">0.300</td><td colspan="3">0.486</td></tr>
<tr><td rowspan="2">HRB</td><td>0.684</td><td>0.347</td><td>0.656</td><td>0.250</td><td>0.680</td><td>0.520</td><td>0.995</td><td>0.250</td><td>0.400</td><td rowspan="2">0.529</td></tr>
<tr><td colspan="2">0.516</td><td colspan="2">0.453</td><td colspan="2">0.600</td><td colspan="3">0.548</td></tr>
<tr><td rowspan="2">TRB</td><td>0.255</td><td>0.554</td><td>0.041</td><td>0.379</td><td>0.420</td><td>0.829</td><td>0.657</td><td>0.574</td><td>0.340</td><td rowspan="2">0.441</td></tr>
<tr><td colspan="2">0.405</td><td colspan="2">0.210</td><td colspan="2">0.625</td><td colspan="3">0.524</td></tr>
<tr><td rowspan="2">ORB</td><td>0.000</td><td>0.515</td><td>0.022</td><td>0.827</td><td>0.073</td><td>0.073</td><td>0.956</td><td>0.952</td><td>0.420</td><td rowspan="2">0.383</td></tr>
<tr><td colspan="2">0.257</td><td colspan="2">0.428</td><td colspan="2">0.073</td><td colspan="3">0.776</td></tr>
</table>

低	中度	高	严重

（3）水资源开发和利用方面，在水资源短缺的流域，其水资源开发速度通常很高，黄河流域就是典型，其水资源开发速度达到65%。尽管其他流域没有达到红色警告线，然而持续的人口膨胀和城市化发展需要越来越多的集中供水，使其同样面临着巨大的挑战。另外，水资源的过度开发（包括地表水和地下水两个方面）将严重地影响水文过程的健康，使得流域面临高生态风险。

（4）生态健康方面，根据目前的数据资料，由于东北亚地区持续的水质恶化，使得该地区中大多数流域，即使是那些脆弱性程度很低的流域，都存在生态风险。另外，也可以从另一个指标——植被（含湿地）覆盖率中看出。在这5个所选流域中，植被覆盖率越低，生态恢复的难度就越大。

（5）管理能力方面，5个流域之间有着较大的差别。一个普遍的问题是用水效率较低。尽管大多数的流域都面临供水短缺的问题，但受众多与水资源管理能力（包括技术和政策）相关因素的影响，用水效率依然十分低。

（6）对于那些拥有国际河流的国家来说，管理冲突是另一项重要指标。尽管这五条河不全

是国际河流，但它们流域面积大，都存在不同等级的跨行政区管理问题。在中国，这3个流域的管理制度相似，但仍然存在一些管理能力上的差异。蒙古2个流域也存在类似状况。

政策建议

根据上述分析，应考虑采用以下政策建议来改善未来的水资源管理。

改善用水效率

尽管这5个流域大部分位于半干旱和干旱地区，并且水资源短缺，然而其用水效率依然非常低。对于用水效率有显著影响的因素主要有2个，分别是发展政策和技术投入。在东北亚地区，农业用水占了主导的地位，但是农业用水效率却比其他产业都要低。因此，农业的发展政策需要重新评估，相关政策应该出台以改善农业用水效率，包括优化农业生产结构和水价经济政策。用水效率的提高同样需要较高的技术支持，例如节水技术的发展。在东北亚地区，对于水资源管理的技术研发投入还相对较低，这应作为国家重要技术改革议程的重要一节。

综合全面的流域管理

目前的管理计划是以政策行政系统为基础的，它在协调统一河流各河段方面表现很弱。流域各部分都有其独特之处，并在流域生态系统中起着不同的作用。目前的中央管理系统使得流域各部分交叉协作能力变得十分有限。因此，为了加强流域尺度的管理制度，应该将管理权下放到各个地方政府。同时，流域管理的关键就在于应该鼓励所有利益相关方的共同参与。此外，流域管理系统的另一个重要作用在于通过水资源分配的协调机制来确保水资源的合理利用。

环境保护和污染控制

在5个所选流域中，除Orkhon河流域在污染控制和植被覆盖等方面都有着较好的生态状态外，其余4个流域都处于严重的环境恶化的威胁之中。环境保护对于恢复退化的生态系统起着非常重要的作用，其手段应包括以确保足够的生态流量的水土侵蚀控制和水土流失控制，以及控制污染物排放的污染控制。

减轻贫困和安全饮用水供应

在今后很长一段时间，减轻贫困是综合流域管理的重要发展任务。贫困人口的基本需求应被优先考虑，包括安全饮用水供应、可选择的生活环境和通过参与水资源管理来改善当地人民解决相关实际问题的能力。

1 概 述

1.1 基本原理

水资源通常被定义为能被人类使用的水的总体。虽然地球上的水的总量巨大（约1.338×10^9 km^3），但能够被使用的淡水资源却非常有限（仅约占2.53%）。大约70%的淡水资源是以冰川、永久积雪、永冻土层或深层地下水等储存形式而不能被人类所利用；大约只有1.065×10^7 km^3的淡水资源能够被人类使用，一般都分布在地表或地下600 m以上的地方。因此，可利用的淡水资源大约只占地球上总淡水资源的30.4%，相当于地球总水资源的0.77%。

随着人口数量的激增和社会经济的发展，人类对水资源的需求日益俱增。与此同时，急速膨胀的人类活动已经对淡水生态系统的健康造成了巨大的负面影响，最直接的表征就是淡水资源的脆弱性凸现。相关调查研究指出，世界上500条重要河流中已有超过一半的河流正在逐渐干涸（UNEP，2002B）。在世界上各水系都面临如此威胁的大背景下，与水相关的生态系统的生物多样性都处于迅速减少的状态，并且其恶化速度比土地生态系统和海洋生态系统都要来的快得多。

联合国诸多报告表明，全世界的用水量在20世纪增长了6倍。可利用淡水资源的供应紧缺、分布不均、管理不当、缺乏基础建设和环境污染等关键问题已造成世界上20%的人口不能获得安全的饮用水，40%的人口缺少基本的卫生条件（ADB，2006）。

因此，作为生态管理的重要组成部分，合理的水资源管理已成为世界走向可持续发展所面临的主要挑战之一，还被纳入各国的可持续发展议程之中。制定一个完整的水资源管理政策，不仅需要全面而综合的知识支撑，更关键的是必须清晰明确地了解水资源的脆弱性。所以，在气候和社会经济变化的背景下，发起水资源脆弱性评估，无疑将能帮助相关部门更好地进行决策。这项工作需要世界上各政府部门和研究机构共同努力，群策群力，而本报告正是这项工作的一个组成部分。

1.2 方法

1.2.1 框架综述

东北亚地区淡水资源脆弱性评估（简称评估）分为两个步骤，即：（1）对该地区选定流域进行逐个深入细致的评估；（2）根据全部选定流域的评估结果，综合分析，得出地区淡水资源脆弱性的评估结果。其中，一个最突出的优点就是对整个流域进行评估的方法。本方法将流

域作为评估的基本单元，收集所有在流域尺度上能反映水文和社会经济过程有着密切联系的科学数据。流域的动态性，即水文和社会经济过程，可以有效地阐明流域水资源的现状和趋势。因此，评估结果将反映流域生态和社会经济间的相互适应过程。

评估中的流域是基于《淡水资源脆弱性评估方法指南》（简称《方法指南》）而选择得出的，同时，《方法指南》也在本报告执行过程中得到了进一步的发展。《方法指南》中的方法是以结果为导向的，其目的在于去很好地了解一个从水资源系统角度出发的流域，包括了基本框架分析和其与当地社会经济系统适应的相互关系。如图1.1所示，评估的概念框架有4个基本组成部分，即水资源基础，水资源开发与利用，水资源生态健康，以及水资源管理。前3者都是表现水文过程、现状与趋势的重要组成部分，通常作为评估水资源脆弱性的理想指标，而最后一部分水资源管理则可以影响前3者，并且反映在复杂水资源系统中社会经济的适应。

只有通过恰当的管理方式，形成水资源基础、水资源开发与利用以及水资源生态健康之

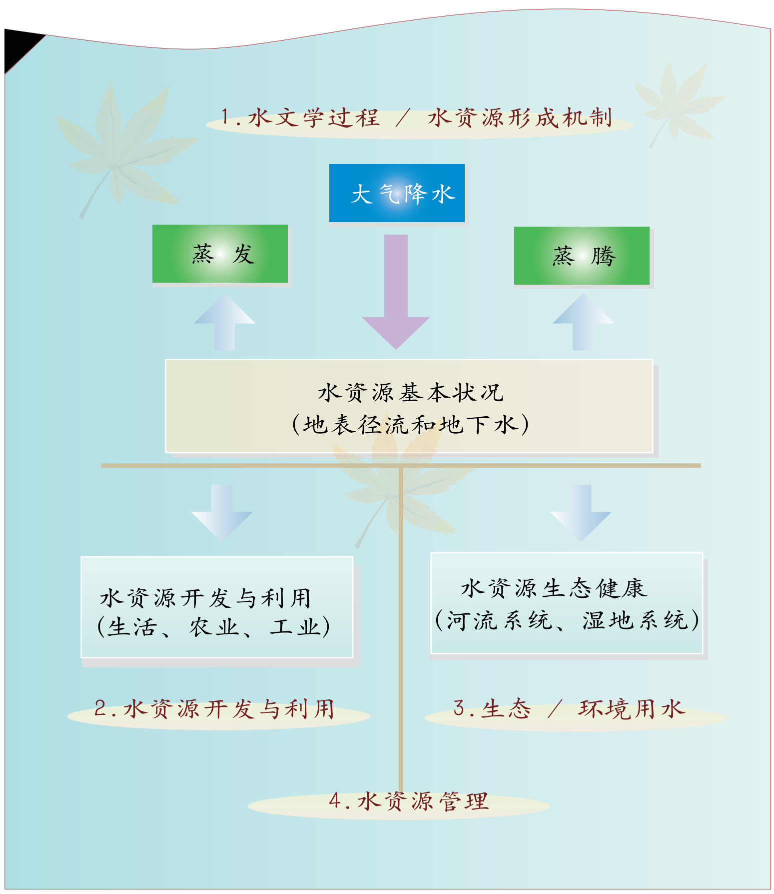

图1.1 流域水资源基本状况及其开发与利用的基本框架

Fig. 1.1 A simplified framework of water resources base, and its development and use in a river basin

间和谐的相互关系，才能实现健康的水资源管理系统，而概念框架的分析正是基于此来进行评估的。因此，流域脆弱性评估就需要对这4个组成部分的现状、趋势以及相互之间的关系有一个准确的认识。

[1] 水资源总量：在不考虑任何水资源开发与利用的前提下，分析水文学平衡，重点在水资源形成的天然水文学过程，及其与气候变化和当地生物物理条件的关系。

[2] 水资源开发与利用：分析水资源供需平衡，重点在通过工程手段，分析水资源开发的承载力及其与水资源利用的关系。其中，水资源利用包括生活用水，城市化现代化进程中的用水发展趋势，以及水资源对经济发展的支撑作用。

[3] 水资源生态健康：分析水资源维持流域系统健康的生态功能，供需平衡关系以及在此过程中的其他关键问题。与此同时，还需要分析水资源开发与利用（污染）之后的水质状况，及其对流域水资源的长远影响。

[4] 水资源管理：上述3个组分都是基于淡水资源开发与利用的自然过程或自然适应。然而，自然过程往往受到社会适应淡水资源容量的巨大影响，也就是说，淡水资源管理能力在建立健康淡水资源开发与利用的系统中起着重要作用。因此，评估中还应考虑管理能力对评价制度安排、跨界合作和其他淡水资源管理相关因素状态和趋势的作用。

基于上述框架，本报告评估由以下3个步骤组成：

[1] 诊断每个组成部分的关键问题：通过全面地对流域水文数据库的综合分析，阐明在评估框架内各组成部分的现状和发展途径，并以可持续水资源管理为目标，明确各组成部分内现存的关键问题；

[2] 通过DPSIR方法具体分析关键问题：应用DPSIR方法，深入分析关键问题各驱动因子、压力、现状、影响和响应之间的内在因果关系，为政策建议提供精确的技术支持；

[3] 通过计算脆弱性指数进行综合评价：综合评价应用一套综合脆弱性指数系统方法（VIS），其目的是获得对描述流域脆弱现状指数矩阵的总体把握，并使各流域之间的结果具有可比性。

VIS是由一系列指标组成的，这些指标可以分为两层结构。第一层，包括了四个变量，它们分别代表评估框架中的四个关键组成部分，即资源压力、发展压力、生态健康和管理挑战。因此，一个流域的脆弱性可以表达为式：

第二层则包括了上述四个变量的一系列可计算参数，如表1.1所示。

$$VI = f\,(RS, DP, EH, MC)$$

其中， VI＝脆弱性指数，RS＝资源压力，DP＝发展压力，EH＝生态健康，MC＝管理能力

第二层则包括了上述四个变量的一系列可计算参数，如表1.1所示。

表1.1 淡水资源评估脆弱性指数系统指数结构

Table 1.1 Indicator structure of Vulnerability Index System for freshwater resources assessment

第一层	第二层	符号	定 义	计算方法
资源压力 (RS)	水资源匮乏	RSs	区域内人均水资源量与公认最低人均水资源量（1,700 m³/人）比值	$\begin{cases} RS_S=\frac{1700-R}{1700} & (R\leq 1700) \\ RS_s=0 & (R>1700) \end{cases}$
	水资源变化	RSv	过去50年内降水量的变异系数	$\begin{cases} RS_v=\frac{CV}{0.3} & (CV<0.3) \\ RS_v=1 & (CV\geq 0.3) \end{cases}$
发展压力 (DP)	水需求压力	DPs	总水资源中的供水比例	$DP_S=\frac{WR_S}{WR}$
	安全饮用水可获得性	DPd	不能获得安全饮用水的人口比例	$DP_d=\frac{p_d}{p}$
生态健康 (EH)	水污染	EHp	总水资源中排放的废水比例	$\begin{cases} EH_p=\frac{WW/WR}{0.10} & (WW<0.10\times WR) \\ EH_p=1 & (WW\geq 0.10\times WR) \end{cases}$
	生态退化	EHe	裸露土地（没有植被）比例	$EH_e=\frac{A_d}{A}$
管理能力 (MC)	用水效率	MCe	用水效率水平（单位GDP用水量）	$\begin{cases} MC_e=\frac{WE_{wm}-WE}{WR_{wm}} & (WE<WE_{wm}) \\ MC_e=0 & (WE\geq WE_{wm}) \end{cases}$
	改进的卫生设施	MCs	无法获得改进卫生设施的人口比例	$MC_S=\frac{P_S}{P}$
	管理能力	MCc	流域跨界问题的管理能力	咨询

具体计算方法可以参见方法指南，而所得评价结果的解释列于表1.2中 。

表1.2 脆弱性指数的参考解释

Table 1.2 Reference sheet for interpretation of Vulnerability Index

脆弱性指数	解 释
低 (0.0 – 0.2)	从资源储备、发展实践、生态状况和管理能力角度综合分析是一个健康的流域，没有严重的政策需要建议施行。然而，在评估组分中仍然可能存在一或两个中度的问题，通过检查脆弱性指数结构可以提出适当政策调整。
中度 (0.2 – 0.4)	该流域在实现可持续水资源管理方面大致处于好的状态。然而，仍然可能面临技术支持或者管理能力建设方面的挑战。因此，流域的政策设计应集中于对脆弱性指数结构检查后所得的主要问题，并设计强有力的政策干涉以克服关键的限制因素。
高 (0.4 – 0.7)	该流域面临较高压力，需要投入更多努力来设计政策，从而能够获得技术支持和政策保证以减轻高度压力。根据着眼重建处理主要威胁管理能力的原则，制定更长远的战略发展计划。
严重 (0.7 – 1.0)	该流域的水资源系统严重退化，管理配备落后。恢复流域的水资源需要来自政府和公众的高度认同和支持。恢复工作将是一个长期的过程，需要通过与国际、国家、当地主体的协调参与制定流域水平的整体计划。

在完成选定流域的评估工作之后，应用与之具有类似的评估结构，对亚区进行综合评估。亚区综合评估报告包括两个相关联的部分：

[1] 应用评估结构，对亚区水资源脆弱性作总体介绍和分析；

[2] 基于选定流域的评估结果，对关键特征和问题进行更为深入的技术分析。根据前面两部分的关键点和选定流域脆弱性指标的计算和绘图，亚区评估的总结部分将提供综合评价和可供选择的政策建议。

1.2.2 评估过程

根据整体框架，东北亚地区的评估工作，可分为以下三个阶段进行：

[1] 选定流域的评估：中国和蒙古2个研究团队分别对选定的5个流域进行深入分析。这些流域分别是中国的长江流域（CRB）、黄河流域（HRB）和松辽流域（SLB），以及蒙古的Orkhon河流域（ORB）和Tuul河流域（TRB）。当前期的案头工作完成后，2个团队集合为1个工作组，对评估中的方法问题进行讨论，包括数据分析、脆弱性指数计算等，形成各选定流域评估报告初稿。

[2] 亚区的综合评估：根据选定流域的评估报告，准备亚区综合评估报告。工作组应用评估体系对亚区淡水资源现状和趋势进行更加详细的分析。基于上述分析结果，应用DPSIR框架对亚区关键问题进行具体评估。再通过深入分析淡水资源脆弱性指数，提出相关适合的政策建议，并形成亚区综合评估报告初稿。

[3] 审阅评估报告：成立审阅评估报告的专家团。由专家团对选定流域评估报告和亚区综合评估报告进行审阅，工作组再根据专家团提出的意见和建议，进一步完善上述报告，并确定报告终稿。

1.3 报告结构

报告分为3个部分：(1) 亚区概况和亚区内所有国家影响淡水资源的主要因素；(2) 基于5个选定流域案例的研究结果，深入分析亚区淡水资源脆弱性评估；(3) 附件：5个选定流域评估报告全文。

2 东北亚地区淡水资源综览

2.1 地区概况

东北亚地区幅员辽阔，陆地总面积为11,764,596 km^2，约占世界的1/12；濒临太平洋，海岸线长86,199 km，拥有岛屿约22,000个 (MFA of PRC, Xinhuanet, GOVCN-A, CSY2006, and MSY2005) 。东北亚地区由5个国家组成，分别为中华人民共和国、蒙古国、日本国、大韩民国和朝鲜民主主义共和国，地理位置如图2.1所示。

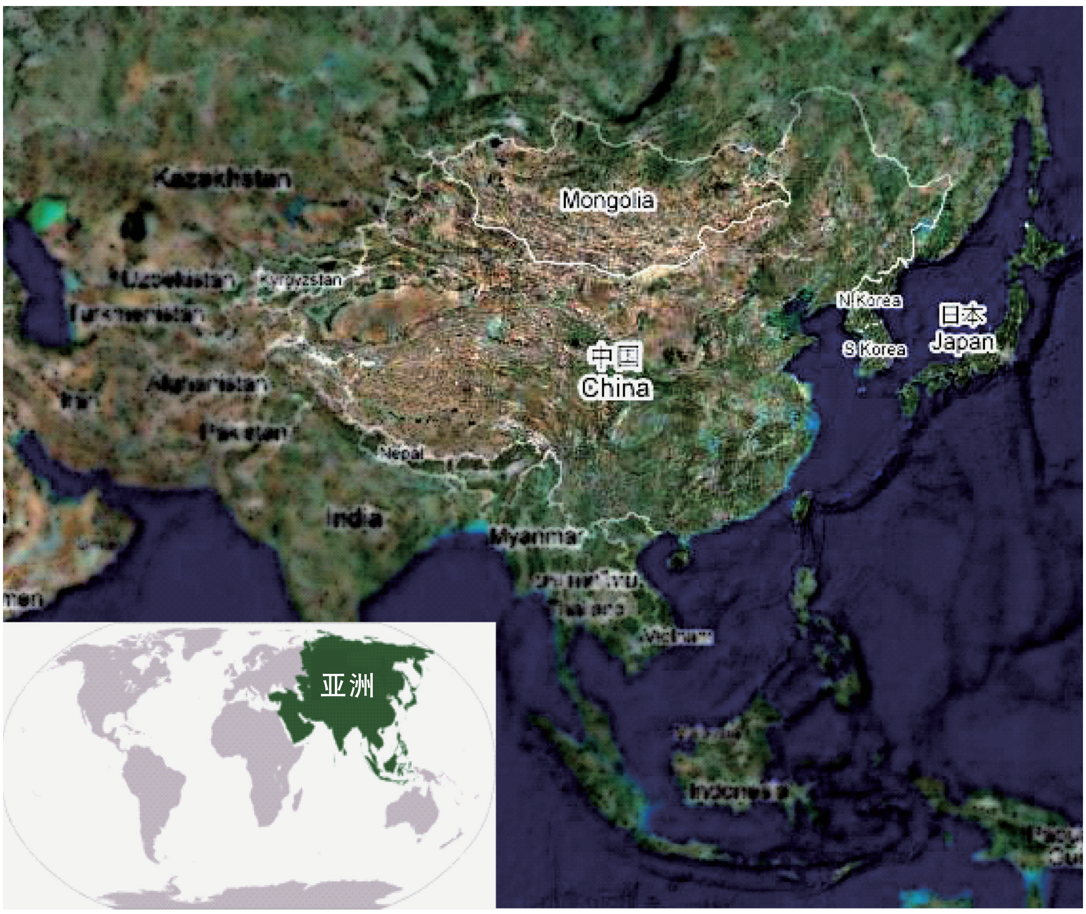

图2.1 东北亚地区的地理位置*(Google Earth)*
Fig. 2. 1 Northeast Asia sub–region (Google Earth)

2.1.1 地形

东北亚地区地形复杂多样，拥有陆地上5种基本的地形类型，即高原、平原、盆地、山地和丘陵，主要分布如表2.1所示。其中，山地占54.6%，成为东北亚地区最主要的地形类型。一般而言，山地普遍具有坡度陡峭、地势崎岖的特点。因此，给东北亚地区的水能资源提供了良好的水势落差的天然优势。据统计，仅中国就拥有680,000,000 kw的水能蕴藏量(CSY, 2006)。

表2.1 东北亚地区地形类型分布

Table 2.1 Distribution of landform types in Northeast Asia sub-region

	中国	蒙古	日本	韩国	朝鲜
高原	西北部 西南部	北部	—	东北部 西北部	东北部
平原	东部	东部	东北部 中部 西南部	南部 西部	南部
盆地	西北部 中部	西南部	—	—	—
山地	中部	西部 北部 中部	东北部 中部 西南部	东部 北部	东部 南部 北部
丘陵	东南部 西南部	东南部	—	南部 西部	—

东北亚地区地势西高东低，自西向东构成三级阶梯。第一级阶梯是青藏高原，平均海拔在4000 m以上，岭谷并列，雪峰连绵，中国的第一和第二大河流长江、黄河就分别发源于青藏高原的唐古拉山北麓和巴颜喀拉山北麓；第二级阶梯相间分布着广阔的高原和盆地，平均海拔在1000~2000 m，主要包括蒙古高原、内蒙古高原、黄土高原、云贵高原、岭西高原、镇安高原、准噶尔盆地、塔里木盆地、柴达木盆地和四川盆地等；第三级阶梯交错分布着平均海拔1000 m以下的丘陵和200 m以下的平原，主要包括东北平原、华北平原、长江中下游平原、珠江三角洲平原、关东平原、石狩平原、新潟平原、浓尾平原和大阪平原等。另外，从第三级阶梯继续向海洋延伸，就是浅海大陆架。这个区域一般深度不大，坡度较缓，蕴涵着丰富的海洋资源。

2.1.2 气候

东北亚地区幅员辽阔，跨纬度较广，距海远近差距较大，同时，该地区地形类型丰富、地势高低起伏、山脉走向不一，从而形成了多种多样的气温—降水组合，使得东北亚地区同时拥有大陆性气候、海洋性气候和季风气候等3种气候类型（表2.2）。

表2.2 东北亚地区气候类型分布

Table 2.2 Distribution of climate types in Northeast Asia sub–region

	中国	蒙古	日本	韩国	朝鲜
大陆性气候	√	√			
海洋性气候			√	√	√
季风气候	√		√	√	√

[1] 大陆性气候的主要特征：夏有酷暑，冬有严寒，年内温差较大（表2.3），全年降水主要集中于夏季。代表区域：蒙古、中国西北部和北部。

[2] 海洋性气候的主要特征：夏无酷暑，冬无严寒，年内温差较小，全年温和湿润（表2.3）。代表区域：日本、韩国、朝鲜。

[3] 季风气候的主要特征：夏季盛行来自东南面太平洋和西南面印度洋的偏南风，性质温暖、湿润，在其影响下，降水普遍增多；冬季盛行来自亚洲内陆（例如，西伯利亚）的偏北风，性质寒冷、干燥，在其影响下，降水普遍减少。全年季节变化明显，雨热同季。代表区域：中国东部和南部、日本、韩国、朝鲜。

表2.3 东北亚地区气温

Table 2.3 Temperature characteristics of Northeast Asia sub–region

	中国	蒙古	日本	韩国	朝鲜
多年平均气温（℃）	4～23	0.25	10～15	11～16	8～12
夏季平均气温（℃）	31	17.5	28	27	27
冬季平均气温（℃）	－17	－20.2	－6	－8	－10

数据来源: MFA of PRC, Xinhuanet, CSY 2006, and MSY 2005

通常来说，当日平均气温稳定升到10°C以上时，大多数农作物才能活跃生长，因此，可以将日平均气温连续≥10°C的天数叫生长期。同时，又可以把生长期内每天平均气温累加起来，这个温度总和被称作积温。一个地区的积温，反映了该地区的热量状况。所以，根据积温分布，可将东北亚地区划分为5个温度带，即热带、亚热带、暖温带、中温带和寒温带（表2.4）。另外，由于中国青藏高原地区受地形、地貌条件特殊性的影响，不能用温度带来进行描述、分类该地区的气温变化和农作物生长耕作规律，因此，一般用“青藏高原区”来作为该地区温度带的命名。

表2.4 东北亚地区温度带分布

Table 2.4 Distribution of temperature zones in Northeast Asia sub–region

		热带	亚热带	暖温带	中温带	寒温带
积温（℃）		> 8,000	4,500 ~ 8,000	3,400 ~ 4,500	1,600 ~ 3,400	< 1,600
作物生长期（天）		365	218 ~ 365	171 ~ 218	100 ~ 171	< 100
分布范围	中国	1.海南 2.云南、广东、台湾南部	1. 秦岭淮河以南 2.青藏高原以东	1.大部分黄河中下游地区 2. 新疆南部	1.黑龙江东部 2.吉林、辽宁 3.内蒙古大部分 4.新疆北部	1.黑龙江北部 2.内蒙古东北部
	蒙古	—	—	—	1.东部 2.西部 3.南部	1.北部 2.东北部
	日本	—	九州南部	1.九州北部 2.本州、四国	北海道南部	北海道北部
	韩国	—	—	全境	—	—
	朝鲜	—	—	全境	—	—

数据来源: GOVCN-B, MFA of PRC, and CSY, 2006

2.1.3 自然资源

2.1.3.1 土地资源和土地利用

在东北亚地区，占世界陆地总面积1/12的土地上生活着占世界1/4的人口，人均土地面积仅为0.0078 km^2，是世界平均水平的1/3 (MFA of PRC,Xinhuanet,and CYS,2006)。因此，东北亚地区土地资源具有绝对数量大、人均占有少的特点。同时，东北亚地区人均土地面积分布极其不均。除蒙古外，其他四国人均土地面积都十分匮乏，并且均未达到东北亚地区的平均水平（表2.5）。其中，人均土地面积最少的日本仅为蒙古的约0.5%。

表2.5 东北亚地区土地资源

Table 2.5 Land resources in Northeast Asia sub–region

	中 国	蒙 古	日 本	韩 国	朝 鲜
土地面积 (km^2)	9,600,000	1,564,116	377,880	99,600	123,000
人均土地面积 (km^2 /人)	0.0073	0.6110	0.0030	0.0021	0.0053

数据来源: MFA of PRC, Xinhuanet, CSY 2006, and MSY 2005

受地形、地貌、气候等自然因素的直接影响，东北亚地区土地资源的利用类型多种多样，为农、林、牧、副、渔多种经营和全面发展提供了有利条件。但值得注意的是，有些土地类型难以开发利用，例如，中国的沙质荒漠、戈壁合占约国土总面积的12%。从表2.6中可以看出，东北亚地区耕地面积为1,390,046 km^2，比重约为19.59%；森林面积为2,305,080 km^2，比重约为19.59%；牧场面积为4,285,510 km^2，比重约为36.42%；其他面积为2,732,876 km^2，比重约为23.23%。因此，东北亚地区土地资源利用类型中耕地比重最小 (GOVCN-C)。

东北亚地区近年来耕地面积减少与人口数量增加的矛盾已变得越来越尖锐。东北亚地区人均耕地面积仅为0.00122 km^2 (表2.6)，不仅远低于世界平均水平0.0367 km^2/ 人，而且仅为世界粮农组织（FAO）所规定的人均耕地面积警戒线0.0053 km^2的约1/4。

表2.6 东北亚地区土地利用类型分布

Table 2.6 Distribution of land use types in Northeast Asia sub-region

	中国	蒙古	日本	韩国	朝鲜
耕地面积 (km^2)	1,300,392	1,758	49,896	19,500	18,500
耕地面积比例 (%)	13.54	0.11	13.20	19.58	15.04
人均耕地面积 (km^2 / 人)	0.00099	0.00069	0.00039	0.00041	0.00080
森林面积 (km^2)	1,749,100	147,480	251,500	64,000	93,000
森林面积比例 (%)	18.22	9.43	66.56	64.26	75.61
牧场面积 (km^2)	3,133,300	1,152,210	—	—	—
牧场面积比例 (%)	32.64	73.67	—	—	—
内陆水域面积 (km^2)	174,700	9,676	—	—	—
内陆水域面积比例 (%)	1.82	0.62	—	—	—
其他土地面积 (km^2)	2,375,800	252,992	76,484	16,100	11,500
其他土地面积比例 (%)	24.75	16.17	20.24	16.16	9.35

数据来源：MFA of PRC, Xinhuanet, CSY 2006, and MSY 2005

2.1.3.2 生物资源

东北亚地区动植物种类丰富，分布错综复杂，是世界上动植物资源最丰富的地区之一。在东部季风区，有热带雨林，热带季雨林，中、南亚热带常绿阔叶林，北亚热带落叶阔叶常绿阔叶混交林，温带落叶阔叶林，寒温带针叶林，以及亚高山针叶林，温带森林草原等植被类型。在西北部和青藏高原地区，有干草原，半荒漠草原灌丛，干荒漠草原灌丛，高原寒漠，高山草原草甸灌丛等植被类型。

以中国为例，据统计有种子植物300个科、2,980个属、24,600个种，兼有寒、温、热三带的植物。其中，①被子植物2,946属，占世界被子植物总属的23.6%；②比较古老的植物，约占世界总属的62%；③用材林木1,000多种、药用植物4,000多种、果品植物300多种、纤维植物500多种、淀粉植物300多种、油脂植物600多种、蔬菜植物80多种。中国还有陆栖脊椎动物约2,070种，占世界陆栖脊椎动物的9.8%。其中，鸟类1,170多种、兽类400多种、两栖类184种，分别占世界同类动物的13.5%、11.3%和7.3%（GOVCN-D）。

2.1.3.3 矿产资源

东北亚地区幅员辽阔，地质构造复杂，蕴藏着种类繁多的矿产资源。据统计，东北亚地区目前已探明储量的矿产资源种类均值约为170种。其中，钨、锑、稀土、钼、钒和钛等储量居世界首位，煤、铁、铅、锌、铜、银、汞、锡、镍、磷灰石、石棉、石墨和菱镁矿储量居世界前列（表2.7）。

表2.7 东北亚地区矿产资源分布

Table 2.7 Distribution of mineral resources in Northeast Asia sub–region

	中国	蒙古	日本	韩国	朝鲜
种类	157	80	10	280	300
金属矿产资源（大储量）	1.钨 2.锑 3.钼 4.钍 5.钒 6.钛 7.铁 8.锌 9.铅 10.银 11.汞 12.锡 13.镍 14.金 15.铜 16.铝 17.铬 18.菱镁矿	1.铁 2.铜 3.钼 4.锌 5.银 6.金	—	1.铁 2.铜 3.铅 4.锌 5.银 6.金	1.铁 2.铜 3.铝 4.锌 5.银 6.金 7.菱镁矿
非金属矿产资源（大储量）	1.煤 2.石油 3.天然气 4.磷 5.石棉 6.萤石 7.重晶石 8.硅土 9.滑石 10.高岭土 11.石墨	1.煤 2.萤石 3.磷 4.石油	1.煤 2.石灰石	1.石灰石 2.磷 3.硅土 4.滑石 5.萤石 6.高岭土 7.无烟煤 8.云母 9.石棉	1.石墨 2.煤 3.石灰石 4.云母 5.石棉

数据来源：GOVCN-D, MFA of PRC, CSY 2006, and MSY 2005

2.1.4 人口

东北亚地区总人口约为1,508,263,000，约占世界的1/4，人口密度约为128人/km^2，属于世界上人口最为稠密的地区之一（图2.2）。

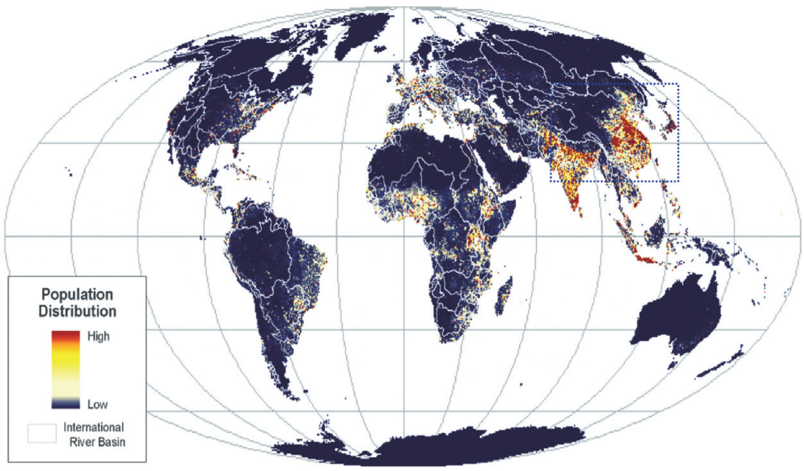

图2.2 东北亚地区人口密度（蓝色虚线矩形）
Fig. 2.2 Population density in Northeast Asia sub–region (blue dash rectangle)(UNEP, 2002B)

根据近5年来的统计数据，东北亚地区年均人口自然增长率为9.36‰，与20世纪80、90年代相比，增长率持续呈现减少的变化趋势。与此同时，东北亚地区老龄化率却在逐年递增。相关报道（2000年）指出，日本、韩国和中国已步入老龄化社会行列，其65岁及以上人口占总人口的比例分别为17.3%、7.0%和6.96%。2002年，东北亚地区的城市人口率约为42%，从表2.8中可以看出，该地区内发达国家（日本和韩国）的城市人口率普遍高于发展中国家（中国、蒙古和朝鲜）。

表2.8 东北亚地区人口概况
Table 2.8 General characteristics of population in Northeast Asia sub–region

	中 国	蒙 古	日 本	韩 国	朝 鲜
人口（百万）	1,307.56	2.56	127.74	47.254	23.149
人口密度（人/km^2）	135	2	338	474	188
人口增长率（‰）	6.234	17	6.54	9.2	7.85
城市人口率（%）	37.63	56.99	78.51	80.30	59.40

数据来源：MFA of PRC, CSY 2006, and MSY 2005

东北亚地区共有59个民族，其分布为：①中国有56个民族，其中汉族为主体民族，占总人口的91.59%；②蒙古有5个民族，其中蒙古族为主体民族，占总人口的90%；③日本有3个民族，其中大和族为主体民族，占总人口的98%；④韩国和朝鲜都只有一个民族，同为朝鲜族（表2.9）。

表2.9 东北亚地区民族

Table 2.9 Names of nationalities in Northeast Asia sub−region

序号	民 族	序号	民 族	序号	民 族	序号	民 族
1	汉族	16	哈尼族	31	达斡尔族	46	德昂族
2	蒙古族	17	哈萨克族	32	仫佬族	47	保安族
3	回族	18	傣族	33	羌族	48	裕固族
4	藏族	19	黎族	34	布朗族	49	京族
5	维吾尔族	20	傈僳族	35	撒拉族	50	塔塔尔族
6	苗族	21	佤族	36	毛南族	51	独龙族
7	彝族	22	畲族	37	仡佬族	52	鄂伦春族
8	壮族	23	高山族	38	锡伯族	53	赫哲族
9	布依族	24	拉祜族	39	阿昌族	54	门巴族
10	朝鲜族	25	水族	40	普米族	55	珞巴族
11	满族	26	东乡族	41	塔吉克族	56	基诺族
12	侗族	27	纳西族	42	怒族	57	大和族
13	瑶族	28	景颇族	43	乌孜别克族	58	阿伊努人
14	白族	29	柯尔克孜族	44	俄罗斯族	59	琉球族
15	土家族	30	土族	45	鄂温克族		

数据来源: GOVCN-E and MFA of PRC

注: ①民族序号为 1～56 属于中国; ②民族序号为1, 2, 17, 43和44 属于蒙古;
③民族序号为57～59 属于 日本; ④民族序号为10 属于朝鲜和日本。

2.1.5 经济发展

2006年，东北亚地区GDP增长率约为9.275%（除朝鲜），是世界预期增长率的约1.5倍，GDP总量约为76,343亿美元，人均GDP约为5,062美元，约为世界平均水平的62%。由此表明，整体而言，东北亚地区经济发展速度较快、市场运作活力较强、人民生活水平较高，但从表2.10中可以看出，该地区内的发达国家与发展中国家之间的经济实力依然存在着巨大的差距。

表2.10 东北亚地区2006年GDP概况

Table 2.10 General Introduction of GDP in Northeast Asia sub–region

	中 国	蒙 古	日 本	韩 国	朝 鲜
GDP 增长率（%）	10.7	18.6	2.8	5	—
GDP 总量（亿美元）	23,290	22.7	45,905	7,113.6	20.4
人均GDP（美元）	1,352	756	36,486	14,649	85

数据来源：IMF, WB, CSY 2006, and MSY 2006

东北亚地区产业机构有以下特点：

[1] 作为该地区的发达国家，日本和韩国的产业结构比例，即第一产业：第二产业：第三产业，都约为1∶3∶6，由此表明，两国的支柱产业同为第三产业，都已迈入了“后工业化社会”时期。在大力发展高新技术微电子信息产业的同时，两国的服务业也得到了十分迅猛的发展。截至2000年，日本服务业在第三产业中的比例已上升至19.2%，促使其快速增长的主要原因大致可分为3点：(1) 软件等与信息通信有关服务的增长，(2) 在高龄化背景下医疗服务的增长，(3) 对个人服的需求的增长。

[2] 中国既是一个发展中国家，同时又是世界第4大经济体，随着近十年来GDP持续快速的增长，产业结构也在不断的调整和优化。根据2006年的统计数据，中国第一产业、第二产业、第三产业的比例分别为12.6%、47.5%和39.9%。目前，中国处于第二产业高速发展时期，重工业比重显著增长，电力、钢铁、机械设备、汽车、造船、化工、电子、建材等成为国民经济成长的主要动力。

[3] 朝鲜的产业结构中第一产业和第二产业占了大部分比例，其中第二产业比例为50%，以采矿、冶金、机械、电力、纺织、化工等为主。

[4] 蒙古是该地区中唯一一个以第一产业（畜牧业）为支柱产业的国家，这与其海陆分布、地

形条件和气候类型有着密切的关系。截至2002年，蒙古各种牲畜存栏数约为2,368万头（万只）。在第二产业方面，蒙古以轻工、食品、采矿和燃料动力为主，2002年占GDP的23%。

2.2 淡水资源概况

2.2.1 淡水资源特征

受地理位置、地形地貌、气候等多种自然因素的综合影响，东北亚地区水资源特征主要表现为以下5个方面：①河流流程较长、②流域面积较广、③水势落差较大、④国际流域分布较多，⑤各国间差异显著，其主要河流水系分布如表2.11所示。

表2.11 东北亚地区主要流域分布

Table 2.11 Distribution of main river basins in Northeast Asia sub–region

名称	面积（km^2）	干流长度（km）	主要支流	流经国家	水系
Amur流域	2,085,900	4,478	1.松花江 2.嫩江 3.乌苏里江	中国 (42.62%) 蒙古 (9.14%) 朝鲜 (0.01%) 俄罗斯	太平洋
长江流域	1,808,500	6,300	1.嘉陵江 2.岷江 3.雅砻江 4.湘江 5.沅江 6.乌江 7.赣江 8.汉江 9. 澧水 10.资水	中国	
黄河流域	752,443	5,464	1.洮河 2.大黑河 3.汾河 4.渭河	中国	

续表

名称	面积（km^2）	干流长度（km）	主要支流	流经国家	水系
珠江流域	453,690	2,214	1.东江 2.西江 3.北江	中国	太平洋
淮河流域	269,283	1,000	1.白露河 2.东淝河 3.西淝河 4.沂河 5.沭河 6.泗河	中国	
海河流域	263,631	1,090	1.永定河 2.大清河 3.滦河 4.徒骇马颊河	中国	
辽河流域	228,960	1,390	1.老哈河 2.东辽河 3.西辽河 4.新开河	中国	
Herlen流域	108,439	1,090	—	蒙古	
鸭绿江流域	61,900	795	—	中国 朝鲜	
汉江流域	45,343	831	1.北汉江 2.南汉江	韩国 (74.98%) 朝鲜 (25.02%)	
图们江流域	33,000	525	—	中国 (69.70%) 朝鲜	
Onon流域	28,425	298	—	蒙古	

续表

名称	面积（km^2）	干流长度（km）	主要支流	流经国家	水系
洛东江流域	25,000	525	1.南江 2.琴湖江	韩国	太平洋
大同江流域	20,300	439	1.南江 2.载宁江	韩国	
利根川流域	16,840	322	江户川	日本	
石狩川流域	14,330	268	1.空知川 2.雨毫川 3.上川 4.牛朱别川 5.忠别川	日本	
信浓川流域	11,900	367	1.千曲川 2.犀川 3.中津川 4.刈谷田川 5.五十岚川 6.中之口川	日本	
北上川流域	10,150	249	—	日本	

数据来源：UNEP, 2002A, GOVCN-F, MFA of PRC, Xinhuanet, and Myaimarjav & Davaa 1999

2.2.1.1 河流长度

东北亚地区河流总长约493,000 km，其中约80%的河流流程200 km以上，约40%的河流流程500 km以上。不过，在日本，因受狭长岛国形状的地理因素限制，河流流程一般都不超过200 km。全国最长的河流信浓川的流程也只有367 km，这仅为中国第一长河长江流程的约1/17。同时，东北亚地区流程1,000 km以上的河流约95%都集中在中国，这主要是因为其国土幅员辽阔、地形类型丰富、地势高低起伏，使得河流流程往往蜿蜒曲折、急湍跌宕、连绵不绝。

2.2.1.2 流域面积

据不完全统计，东北亚地区流域面积1,000 km^2以上的河流约2,000条，流域面积100 km^2

以上的河流则超过了5,500条。在中国的长江流域，流域面积10,000 km^2以上的支流就有49条，流域面积50,000 km^2以上的支流共9条，分别为嘉陵江、岷江、雅砻江、湘江、沅江、乌江、赣江和汉江。

2.2.1.3 水能

东北亚地区以山地和高原为主要的地形类型。一般而言，山地具有坡度陡峭、地势崎岖的特点，而高原则普遍表现为地势落差的优势。同时，河流又通常发源自海拔高度在2,000 m以上的山地和高原。因此，这些天然条件给东北亚地区拥有良好的水能资源提供了坚实的保障。根据2006年的统计数据，仅中国就拥有680,000,000 kw的水能蕴藏量(CSY, 2006)。

2.2.1.4 国际河流分布

东北亚地区分布着10个国际流域，它们分别是：①Amur流域，②汉江流域，③Har Us Nur流域，④Yenisey流域，⑤Lake Ubsa-Nur流域，⑥Ob流域，⑦Pu-Lun-T’o 流域，⑧绥芬河流域，⑨图们江流域，⑩鸭绿江流域（图2.3）。

图2.3 东北亚地区国际流域的地理位置

Fig. 2.3 International river basins in Northeast Asia sub-region (UNEP, 2002A)

2.2.2 淡水资源概况

除朝鲜外，东北亚地区水资源总量约为3,351 km³，约占世界的1/300；人均水资源量约为2,221 m³，约为世界平均水平的25.7%。由此表明，东北亚地区在水资源总量和人均水资源量上都是最为贫乏的地区之一。同时，从表2.12中可以看出，该地区内各国间的人均水资源量差距悬殊，最大可达约60倍。

表2.12 东北亚地区淡水资源现状

Table 2.12 Status of freshwater resources in Northeast Asia sub–region

	中国	蒙古	日本	韩国	朝鲜
水资源总量 (km³)	2,800	220	400	116	—
人均水资源量 (m³)	2,152	878,600	3,125	2,389	—

数据来源: MFA of PRC CSY 2006, and MSY 2005

2.2.2.1 分布

东北亚地区是世界上降水量较丰富的地区之一，年均降水量约为1,100 mm，空间分布呈现出由西向东、由北向南降水量逐渐增多的变化规律（图2.4）。

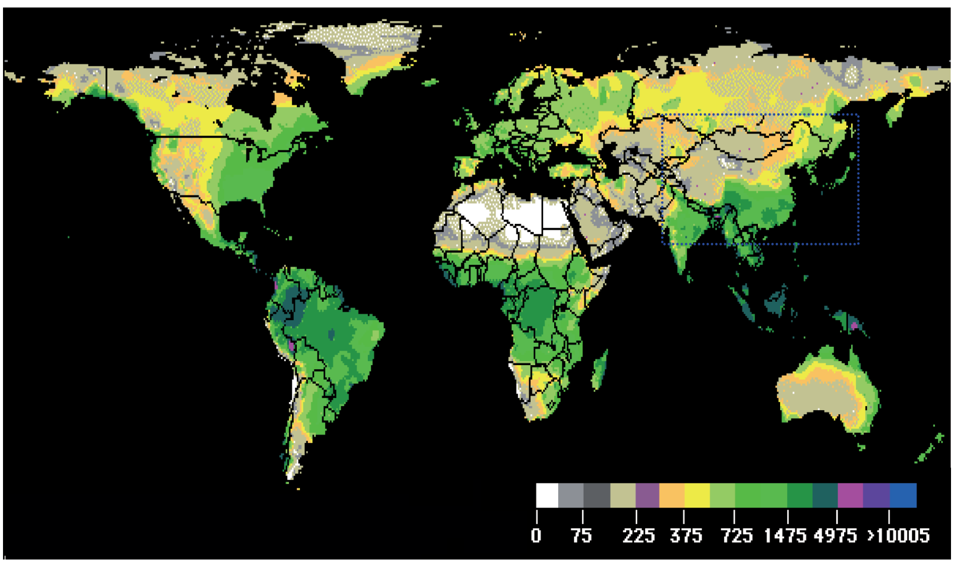

图2.4 东北亚地区年均降水量（蓝色虚线矩形）

Fig. 2.4 Annual precipitation in Northeast Asia sub–region (blue dash rectangle)(FAO–SDRN Agrometeorology Group, 1997)

一般而言，等降水量线图能够较为直观而准确地反映出某一地区的干湿状况。因此，根据等降水量线值，可将东北亚地区分为湿润区、半湿润区、半干旱区和干旱区。从表2.13中可以发现，湿润和半湿润地区约占东北亚陆地总面积的约54%，而干旱和半干旱地区则约占46%，这与东北亚地势三级阶梯的分布有着较为一致的对应性。各国之间干湿状况差异显著，日本、朝鲜最为湿润，韩国稍次之，中国为半湿润半干旱，蒙古最为干旱，其原因主要是由大气降水量与水体蒸发量、土壤水分蒸发蒸腾损失总量之间的不平衡所致。以蒙古为例，结合表2.14可以看出，蒙古的年均降水量为180 mm，在东北亚地区中最少，仅约占平均水平的1/5，但据推算，蒙古的水体蒸发量和土壤水分蒸发蒸腾损失总量却达到了降水量的3～4倍。

表2.13 东北亚地区湿润干旱地区分布

Table 2.13 Distribution of humid–arid zones in Northeast Asia sub–region

		湿润区	半湿润区	半干旱区	干旱区
年均降水量（mm）		> 800	400 ~ 800	200 ~ 400	< 200
干湿状况		降水量 > 蒸发量 土壤水分蒸发蒸腾量		降水量 < 蒸发量 土壤水分蒸发蒸腾量	
植被类型		森林	森林-草原	草原	荒漠
分布范围	中国	1.秦岭-淮河以南 2.青藏高原南部 3.内蒙古东北部 4.黑龙江、吉林、辽宁东部	1.东北平原 2.华北平原 3.黄土高原大部分 4.青藏高原东南部	1.内蒙古高原南部 2.黄土高原其余部分 3.青藏高原大部分	1.新疆西部 2.内蒙古西部 3.青藏高原西北部
	蒙古	—	—	东北部 西北部	全境大部分
	日本	全境	—	—	—
	韩国	全境大部分	北部	—	—
	朝鲜	全境	—	—	—

数据来源: GOVCN-B, MFA of PRC, and CSY, 2006

表2.14 东北亚地区年均降水量

Table 2.14 Annual precipitation in Northeast Asia sub–region

	中国	蒙古	日本	韩国	朝鲜
年均降水量 (mm)	900	180	1,800	1,500	1,100

数据来源: MFA of PRC and CSY, 2006

除蒙古外，东北亚地区因其海陆地理位置的天然分布都拥有季风气候，从而使得该地区的降水量和降水的时空分布受季风气候影响显著，因此可以将一年分为雨季和旱季。从图2.5的柱形图中可以发现，东北亚地区雨季时季风活动频繁，降水量占了全年的70～80%；旱季时，则主要依靠地下水、冰雪融水和水库蓄水的补给。

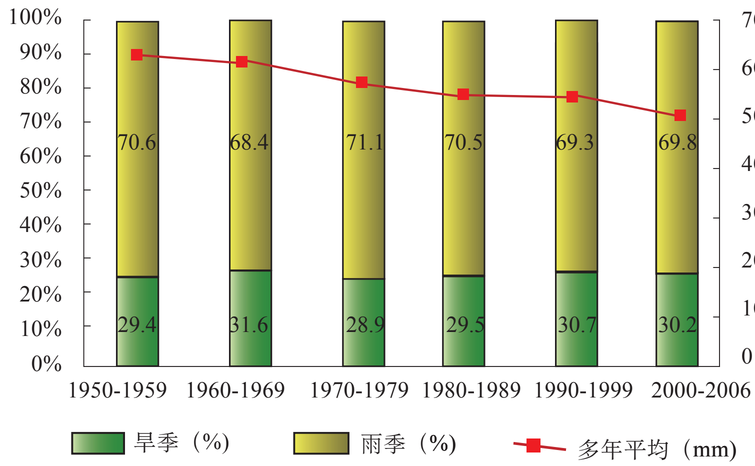

图2.5 东北亚地区降水量特征

Fig. 2.5 Characteristics of precipitation in Northeast Asia sub–region

同时，图2.5中绿色折线所示为对中国长江流域、黄河流域、松辽流域，蒙古Orkhon河流域、Tuul河流域等五大流域多年年均降水量的统计分析。从图中可以发现，这些流域多年年均降水量持续减少，已由1950年的623.9 mm降至2006年的492.8 mm。另外，又根据近200年来洪涝和干旱灾害的频度分析，如图2.6所示，东北亚地区每50年洪灾和旱灾的发生比例都呈增长的趋势，其中旱灾比例增加最快，已达36%。由此表明，水资源短缺和旱涝灾害频发已成为东北亚地区淡水资源的关键问题。

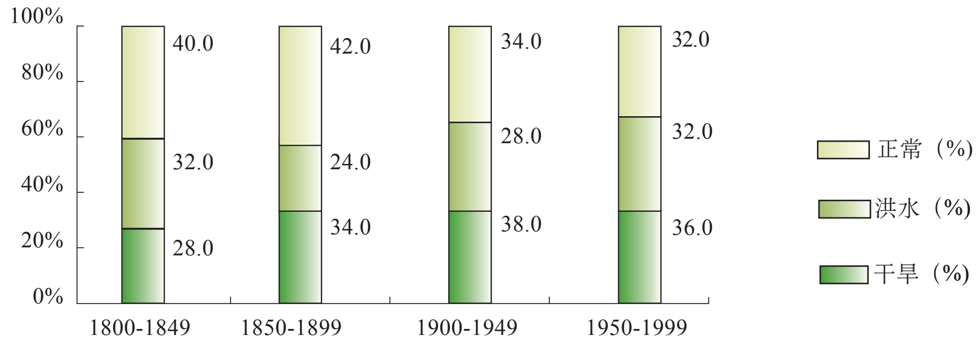

图2.6 东北亚地区旱涝灾害的发生频率

Fig. 2.6 Ratio of drought and flood disasters frequency in Northeast Asia sub-region (Su et al., 2006)

2.2.2.2 开发与利用

除朝鲜外，东北亚地区用水总量约为684.3 km^3，约占世界的29.7%，人均用水量约为454 m^3，约为世界的1.2倍（表2.15）。由此表明，东北亚地区是世界上用水紧张的地区之一。

表2.15 东北亚地区淡水资源使用量

Table 2.15 Freshwater resources use in Northeast Asia sub-region

	中 国	蒙 古	日 本	韩 国	朝 鲜
总使用量（km^3）	563.3	0.4	90	30.6	—
人均使用量（m^3）	432	160	703	630	—

数据来源: MFA of PRC and CSY, 2006

从图2.7、图2.8中可以发现，①东北亚地区用水量最大部分集中在农业，占了总量的60%，同时，东北亚地区淡水资源削减的主导因素也是农业用水；②发展中国家（中国、蒙古）的工业用水量大于生活用水量，而发达国家（日本、韩国）生活用水量则大于工业用水量。根据UNESCO2000年的统计，发达国家人均日生活用水量是发展中国家的10多倍。同时，东北亚地区拥有数量众多的水库和水坝，用来将淡水资源进行贮存、发电和灌溉，但据估算，从水库蒸发的水量已经超过了工业用水和生活用水的总量之和；③中国统计年鉴显示，从2004年起，中国其他用水量的主要功能为生态用水，且在用水总量中的比例逐年增加。

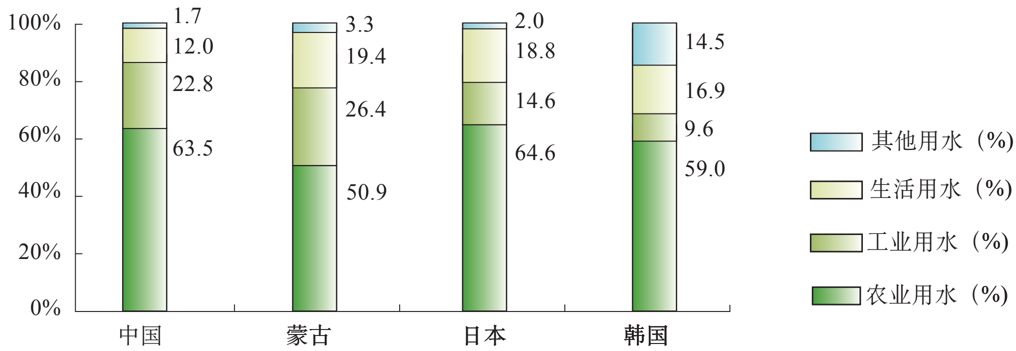

图2.7 东北亚地区各用途用水率的分布

Fig. 2.7 Distribution of water use ratio in Northeast Asia sub−region

截至2002年，东北亚地区约有3.35亿人无法得到改善的饮用水供应（表2.16），约占世界的1/3，形势十分严峻。但相比1990年，东北亚地区目前的改善饮用水供应状态正在处于持续不断地快速增加之中。13年来，共有2.08亿人从中受益。其中，城市人口为1.46亿(70.2%)，农村人口为0.62亿 (29.8%)（表2.16、表2.17）。这样可喜的变化主要归因于1990年开始执行的千年发展目标（MDGs），它的目标是到2015年把全球无法得到改善的饮用水供应的人口比例削减一半。

从表2.18中可以发现，其一，从时间上来看，1990年与2002年东北亚地区城市改善的饮用水供应覆盖率基本保持不变，只有中国的覆盖率下降，其主要原因在于13年间中国城市化发展迅猛，人口激增180,117,100，但是改善的饮用水供应配套设施的发展速度还相应滞后，这种状况常发生在中国西部的中小城市中。1990年与2002年东北亚地区农村改善的饮用水供应覆盖率也变化不大，只有中国的覆盖率上升，其主要原因在于13年间随着中国城市化进程，农村人口锐减40,555,000，同时，中国政府出台的“大力建设社会主义新农村”政策，大大推动了农村改善的饮用水供应配套设施的发展。东北亚地区内还存在严重的饮用水供应城乡不均的问题。2002年，亚区城市安全饮用水可获得人口比例为95.2%，而贫困地区仅为73.8%。另外，发达国家尽管情况较好但仍存在地区差异问题。日本和韩国的安全饮用可获得性在城市和贫困地区均为100%，但中国和朝鲜的覆盖率相对较低，蒙古则最低。

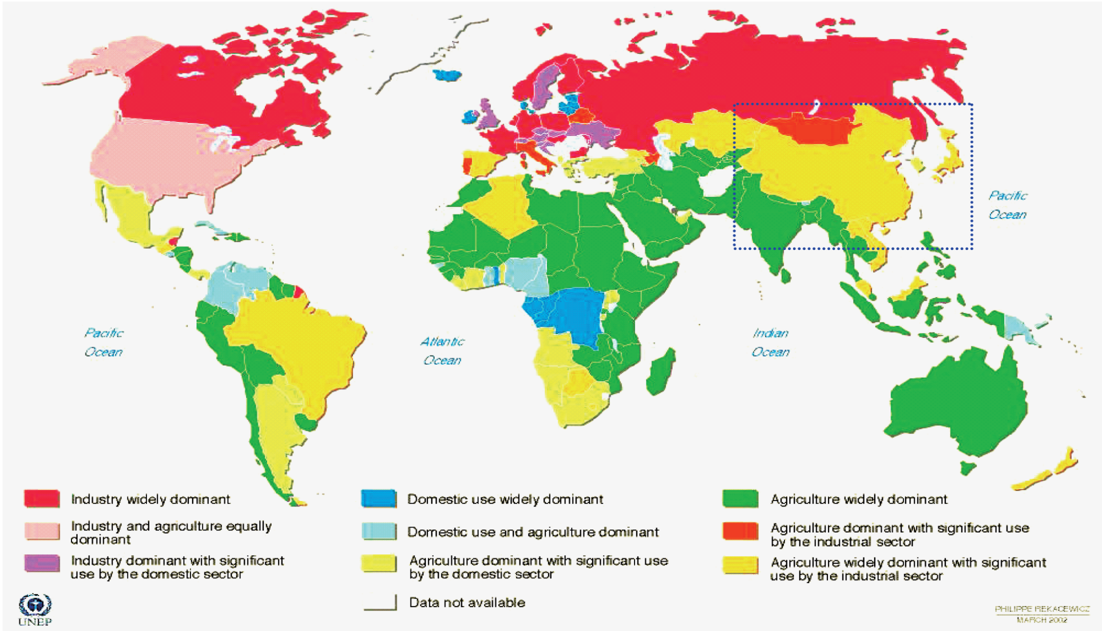

图2.8 东北亚地区淡水资源用水量状况（蓝色虚线矩形）

Fig. 2.8 Freshwater withdrawals in Northeast Asia sub−region (blue dash rectangle) (UNEP, 2002B)

表2.16 “改善”饮用水供应和卫生设施的定义

Table 2.16 Definition of improved drinking water supply and sanitation (ADB, 2006)

	改善	未改善
饮用水供应	接入屋内的连接设施	水域井未得到保护
	输水管道	水域泉得到保护
	井眼	由卖家提供的水
	水源井（泉）受保护	瓶装水
	雨水收集设施	由罐车运来提供的水
	定点消毒	
卫生设施	下水道连接设备	用马桶的厕所
	化粪池	公用厕所
	水冲厕所	旱厕
	具有通风设备的厕所	

数据来源: ADB, 2006

注: ①“改善”的饮用水供应并不是指水资源安全，而是指水资源有更多的可利用性，同时已经采取了一些措施来保护水资源不受污染。

②“改善”的卫生设施通常包括更好的使用性和对排泄物有更安全的处理。

表2.17 东北亚地区饮用水供应
Table 2.17 Drinking water supply in Northeast Asia sub–region

年份	人口（百万）			受益人口（百万）			未受益人口（百万）		
	总数	城市	农村	总数	城市	农村	总数	城市	农村
1990	1,351	446	905	994	445	549	357	1	356
2002	1,502	631	871	1,202	591	611	300	40	260
增加数	151	185	-34	208	146	62	-57	39	-96

数据来源: ADB, 2006

表2.18 东北亚地区饮用水供应覆盖率
Table 2.18 Drinking water supply coverage in Northeast Asia sub–region

		中国	蒙古	日本	韩国	朝鲜
城市人口（千）	1990	311,932	1,263	77,916	31,723	11,574
	2002	492,049	1,459	100,295	37,944	13,750
受益城市人口覆盖率（%）	1990	100	87	100	97	100
	2002	92	87	100	97	100
农村人口（千）	1990	843,373	953	45,621	11,146	8,382
	2002	802,818	1,100	27,145	9,486	8,791
受益农村人口覆盖率（%）	1990	59	30	100	—	100
	2002	68	30	100	71	100

数据来源: ADB, 2006

2.2.2.3 生态健康

东北亚地区约有湖泊30,000个，其中面积1 km^2以上的湖泊2,800多个。湖泊作为河流的天然水库，不仅能够调节蓄洪，而且还拥有众多宝贵的湿地生态系统。然而，随着农业用地和农业用水的需求紧张，围湖造田、过度灌溉和过度放牧等粗放型不可持续的生产方式络绎出现，且比例快速增长。与此同时，矿产开采和森林砍伐都加剧了水土流失，使得湖区泥沙沉积

日益严重。这些人为活动导致了湖泊面积锐减，甚至湖泊干涸消失。以蒙古Tuul河流域为例，在过去的10年中，相继有8个湖泊干涸消失，占了湖泊总数的7.25%。

东北亚地区水体质量下降已越发成为水资源保护中的一个棘手问题。根据2006年的官方统计报告，中国7大水系的水体质量有41%为Ⅲ类水，同比上年下降1%，32%为Ⅳ~Ⅴ类水，同比上年上升2%，27%为劣Ⅴ类水，同比上年下降1%，主要污染指标包括氨氮、石油类、高锰酸盐、挥发酚和BOD等（GOVCN-G）。

2.2.2.4 管理

对一个水资源严重稀缺的地区来说，维持水资源供需平衡的关键措施之一就是提高水资源利用的效率。显而易见，水资源利用效率是一个包含众多变量的函数，其中包括技术、价格和知识等。单位GDP用水量，作为一个非常重要的价格指示标，能够较为真实而准确地反映各级政府在节约水资源和环境保护方面所作出的成绩。

除朝鲜外，东北亚地区单位GDP用水量约为11.11美元/m^3，比世界平均水平约低10%（图2.9）。其中，蒙古单位GDP用水量最高、中国次之、韩国再次、日本最低，这一排序与东北亚地区各国人均GDP排序正好相反。由此表明，经济越发达、综合国力越强的国家在节水意识、用水效率和治水措施等方面都更占有优势，从而产生良性循环，进一步促进该国的可持续发展。与此同时，发达国家和发展中国家之间单位GDP用水量存在巨大差距。例如，蒙古单位GDP用水量，相当于世界平均水平的28.6%，约为日本的1/15。因此，东北亚地区的节水潜力同样巨大。

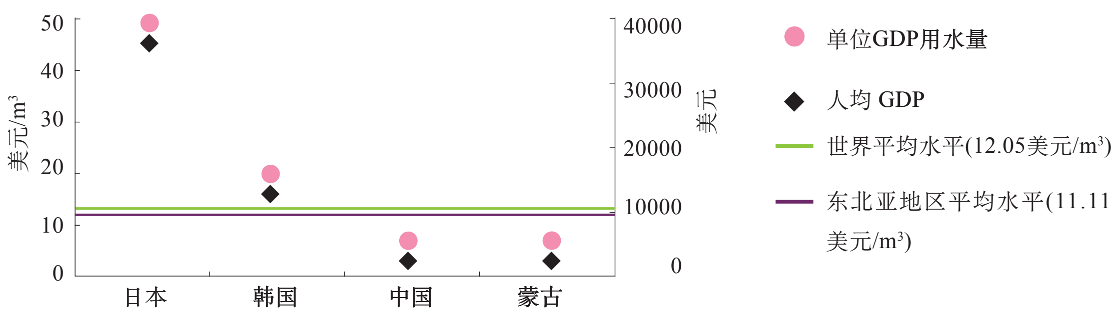

图2.9 东北亚地区水利用效率现状

Fig. 2.9 Water use efficiency state in Northeast Asia sub−region
(MFA of PRC, Xinhuanet, and CYS, 2006)

截至2002年，东北亚地区约有7.51亿人无法使用上改善的卫生设施（表2.19），其中农村地区占了大多数，约78.3%。但相比1990年，东北亚地区能使用上改善的卫生设施的人口正在持续不断地快速增加之中。13年来，共有3.27亿人从中受益。其中，城市人口为1.5亿 (45.9%)，农村人口为1.77亿 (54.1%)（表2.19、表2.20）。

表2.19 东北亚地区卫生设施

Table 2.19 Sanitation in Northeast Asia sub–region

年份	人口（百万）			受益人口（百万）			未受益人口（百万）		
	总数	城市	农村	总数	城市	农村	总数	城市	农村
1990	1,351	446	905	424	318	106	927	128	799
2002	1,502	631	871	751	468	283	751	163	588
增加数	151	185	-34	327	150	177	-176	35	-211

数据来源: ADB, 2006

表2.20 东北亚地区卫生设施覆盖率（仅有两国数据）

Table 2.20 Sanitation coverage for two countries in Northeast Asia sub–region

		中国	日本
城市人口 (千)	1990	311,932	77,916
	2002	492,049	100,295
受益城市人口覆盖率 (%)	1990	64	100
	2002	69	100
农村人口 (千)	1990	843,373	45,621
	2002	802,818	27,145
受益农村人口覆盖率 (%)	1990	7	100
	2002	29	100

数据来源: ADB, 2006

截至2002年，中国卫生设施的总数增加了67%，即以年均6%的速度增长。在1990～2002年的12年中，中国城市地区卫生设施覆盖率已从23%升至44%，而农村地区卫生设施覆盖率则从仅7%的低水平升至29%，增长速度十分显著。考虑到这一时期人口数量的自然增长和人口迁移等因素，大约有3亿人口从中受益，可以使用改善的卫生设施。相比农村地区，城市地区在中国城市化进程迅猛发展的大背景下仍取得了8%的增长率，这是相当不容易的。尽管农村地区以年均13%的速度改善卫生设施，使近1.74亿人口受益，但不容乐观的是，卫生设施的覆盖率在2002年还仅为29%。在中国，目前仍有超过7.25亿的人口无法获得改善的卫生设施，占了世界总量的1/4（ABD, 2006）。

在国际流域的管理中，涵盖了诸多交互作用的因素，诸如自然因素、行政因素和人文因素等，从而使得国家间共同分享水系的管理工作变得困难重重。水资源匮乏加重、水质恶化、人口数量激增、单边的水资源开发和经济发展水平不均衡等问题都已成为阻碍和扰乱共有河流使用权国家间睦邻友好关系的潜在因素。针对这些因素复合作用容易引起水资源分配上的冲突，学术专家和政策制定者们纷纷提出警告。因此，为了解决现存的争端、避免潜在的冲突，20世纪以来国际社会始终致力于发展和完善国际流域管理的各项法则（UNEP, 2002A）。

东北亚地区的国际流域已签订如下条约（表2.21）。

表2.21 东北亚地区国际流域协定

Table 2.21 International freshwater agreements in Northeast Asia sub–region

流 域	签署方	日 期	协定名称（英语）
Amur	中国 前苏联	1956-08-18	Agreement between the Union of Soviet Socialist Republics and the People's Republic of China on joint research operations to determine the natural resources of the Amur River Basin and the prospects for development of its productive potentialities and on planning and survey operations to prepare a scheme for the multi-purpose exploitation of the Arugun River and the Upper Amur River
	中国 蒙古	1994-04-29	Agreement between the government of the People's Republic of China and the government of Mongolia on the protection and utilization of transboundary waters
	蒙古 俄罗斯	1995-02-11	Agreement between the government of Mongolia and the government of the Russian Federation on the protection and use of transboundary waters
Har Us Nur	中国 蒙古	1994-04-29	Agreement between the government of the People's Republic of China and the government of Mongolia on the protection and utilization of transboundary waters
	蒙古 俄罗斯	1995-02-11	Agreement between the government of Mongolia and the government of the Russian Federation on the protection and use of transboundary waters
Yenisey	蒙古 俄罗斯	1995-02-11	Agreement between the government of Mongolia and the government of the Russian Federation on the protection and use of transboundary waters
Lake Ubsa-Nur	蒙古 俄罗斯	1995-02-11	Agreement between the government of Mongolia and the government of the Russian Federation on the protection and use of transboundary waters
Pu-Lun-T'o	中国 蒙古	1994-04-29	Agreement between the government of the People's Republic of China and the government of Mongolia on the protection and utilization of transboundary waters
	蒙古 俄罗斯	1995-02-11	Agreement between the government of Mongolia and the government of the Russian Federation on the protection and use of transboundary waters

数据来源:UNEP, 2002A

3 东北亚地区淡水资源脆弱性评估

基于上述东北亚地区淡水资源的综览，需要对亚区淡水资源的脆弱性作进一步的系统分析。在中国和蒙古两个研究团队的共同努力下，对选定的5个具有代表性的流域，即中国境内的长江流域、黄河流域、松辽流域和蒙古境内的Orkhon河流域、Tuul河流域，分别作了细致分析。每个流域的完整评估报告都将以附件的形式展示在本报告的最后。以下部分为各流域报告评估结果的摘要。

3.1 选定流域概况

3.1.1 长江流域

长江自西向东流，全长6,300 km，落差5,400 m。长江流域位于北纬24°30′~35°45′，东经90°33′~122°25′，东西距离3,000 km，南北距离1,000 km，总面积1,808,500 km^2，占中国国土总面积的约18.75%。

长江流域地形复杂多样。据统计，其84.7%的地区为山地、高原以及丘陵地带，11.3%为平原，4%为水域。

长江流域跨越3个气候区，它们分别是青藏高寒气候区、西南热带季风气候区和中部亚热带季风气候区。长江流域大部分地区年均气温为16~18°C。与此同时，由于受季风的影响，全年70~90%的降水量集中分布在5月至10月期间。

根据2004年的数据统计，长江流域有221,800 km^{2}的耕地（13.5%），480,000 km^{2}的森林（29.2%）和300,000 km^{2}的牧场（18.3%）。但不容乐观的是，人均耕地面积仅为5,100 m^2，不仅低于世界的平均水平（36,700 m^2），而且还低于世界粮农组织（FAO）同年公布的5300 m^{2}警戒线。

截至2005年，长江流域有2.8537亿农村人口和1.9463亿城镇人口，总数占全国总人口的36.71%。在该流域内，平均人口密度超过265人/km^2，几乎是全国平均水平的2倍。因此，长江流域，尤其是长江中游和下游地区，目前已成为中国人口最稠密的地区之一。

截至2005年，长江流域GDP为64,646.2亿人民币，占全国GDP总量的35.31%。然而，长江流域上、中、下游地区经济发展水平差距显著。例如，下游地区的人均GDP是中游地区的约1.5倍，上游地区的约2倍。

长江流域是中国水资源最丰富的地区之一，水资源总量（即地表径流与地下水资源量之

和减去重复部分）约为10,285.2亿m^3。1997~2004年多年平均降水量是1,091 mm，约合19,730.7亿m^3的总水量，是全国多年平均降水量的1.2倍。由此表明，长江流域是中国降水量丰富的地区。1997~2004年多年平均地表径流为9,739.3亿m^3，同期年均地下水资源为2,423.1亿m^3。然而，受地形条件和气候的影响，该流域水资源的时空分布并不平衡。

长江流域供水总量为1,700～1,800亿m^3，并在近年来呈现稳步增长的趋势。1998～2004年年均供水量为1,725.8亿m^3，其中包括1,641.8亿m^3的地表水和82.3亿m^3的地下水。同期内，长江流域年均用水量为1,718.91亿m^3，其中包括57%农业用水、32%工业用水和11%的生活用水。

如今，长江流域水污染问题十分严重。根据最新的监测数据显示，太湖90%的水质量为V级和劣V级，不能作为饮用水源。该流域土地侵蚀严重，面积达10.63万km^2，导致流域内湖泊面积锐减。20世纪80年代，湖泊总面积12,000 m^2，仅为50年代的45.5%。

中国政府十分重视水资源的管理问题。到目前为止，已经出台了十多部与水资源管理相关的国家性法律法规。1999～2004年间，长江流域水资源利用效率虽然呈持续上升，但水平仍然很低，单位GDP用水量仅为4美元/m^3，远低于2004年世界平均水平12.05美元/m^3。此外，长江流域卫生设施覆盖率状况依然偏低。

长江不是一条国际河流，因此不存在国际争端的问题。然而，长江流域覆盖面积广，上、中、下游地区在地形气候条件和社会经济状况上都有较大差异。因此，不同区域之间的用水冲突仍然是长江流域水资源管理中的关键问题。

3.1.2 黄河流域

黄河自西向东流，全长5,464 km，落差4,480 m。黄河流域位于北纬32°10′～41°50′，东经95°53′～119°05′，东西距离1,900 km，南北距离1,100 km，总面积795,000 km^2（包括42,000 km^2内流区），占中国国土总面积的约8.28%。

黄河流域自西向东大致可分成4个地形区域，即青藏高原、内蒙古高原、黄土高原和黄淮海平原。在黄河下游，河岸高于周围地面，因此被称为悬河。

由于黄河流域大部分地区远离海洋，因此其属于大陆季风气候，上游地区年平均气温为1～8°C，中游地区为8～14°C，下游地区为12～14°C。与此同时，由于受季风的影响，全年70～80%的降水量集中分布在7月至9月期间。

根据2003年的数据统计，黄河流域有132,633 km^2的耕地（16.7%），102,013 km^2的森林（12.8%）和279,427 km^2的牧场（35.1%），其中森林主要分布在下游地区，而草原则主要分布在中上游。

截至2005年，黄河流域有2.5122亿农村人口和1.4903亿城镇人口，总数占全国总人口的

30.61%。在该流域内，平均人口密度超过503人/km^2，几乎是全国平均水平的4倍。因此，黄河流域，尤其是黄河中游和下游地区，目前已成为中国人口最稠密的地区之一。

截至2005年，黄河流域GDP为51,323.5亿人民币，占全国GDP总量的28.03%。黄河流域自古以来就是中国重要的农业生产基地，同时也是以自然资源为优势的工业生产基地。例如，黄河流域拥有全国超过50%的煤储量和约25%的石油储量。

黄河流域是中国水资源最匮乏的地区之一，水资源总量约为597.8亿m^3。1997~2004年多年平均降水量是336.6 mm，约合2,676亿m^{3}的总水量，仅为全国多年平均降水量的37.4%。1950~2000年多年平均地表径流为572亿m^3。大约80%的降水量通过蒸发蒸腾作用回到大气之中，只有20%能够成为地表径流。1997~2004年年均地下水资源为400.9亿m^3。在黄河流域，近70%的降水量集中分布在短暂的雨季，从而大大增加了该地区旱涝灾害的发生频率。

黄河流域2004年供水总量为372亿m^3，约占其水资源总量的59.2%。供水量从上游地区（47.6%）逐渐向中游地区（31.0%）、下游地区（21.4%）递减。上游和下游地区，地表水在供水总量中占最大比重，而中游地区，地下水则占最大比重。1995~2004年，黄河流域年均用水量为388亿m^3，其中包括77.2%农业用水、14.4%工业用水和8.4%的生活用水。据1995年的统计数据，约有3,867.63万人口和2,525.8万头牲畜不能获得安全的饮用水。

黄河中下游地区年水土流失量约为16亿吨，是水体沉积物的主要来源。沉积物能抬高河床，使得黄河成为世界上最危险的悬河。在过去的20年中，排向黄河的废水量翻了一倍并且仍在上升之中，然而，与此同时水体质量却下降了两个等级（超过60%的水资源的水质属于IV级或劣于IV级）。

黄河流域的水资源价值被严重低估，不仅表现在农业用水上，在工业和生活用水上同样如此。1999~2004年间，黄河流域水资源利用效率虽然呈持续上升，但水平仍然很低，上、中、下游地区的单位GDP用水量分别为0.74美元/m^3、3.57美元/m^{3}和1.82美元/m^3，远低于2004年世界平均水平12.05美元/m^3。

黄河流域是中国社会经济发展程度相对落后的地区，全国592个贫困乡镇中269个位于这里。此外，黄河流域的大部分贫困地区目前的卫生设施还十分不足。

黄河不是一条国际河流，因此不存在国际争端的问题。然而，黄河流域覆盖中国9个省级行政区，省际之间对于水资源的管理仍然存在潜在冲突。

3.1.3 松辽流域

松辽流域按照行政区划可分为两个亚流域，即松花江流域和辽河流域。除这两个亚流域中河流外，松辽流域还包括沿黄海和渤海附近的河流，以及中国东北部的几条重要的国际河流，例如，黑龙江、绥芬河、图们江和鸭绿江等。

松辽流域位于北纬40°30′~53°34′，东经116°26′~135°05′，总面积1,249,000 km^2，占中国国土总面积的约13.01%。

据统计，松辽流域的地形分布状况为43.8%山地、26.4%丘陵、28.4%平原和1.4%其他。

松辽流域大部分地区属于西风带，而位于东北角的其他部分则属于温带大陆季风气候。松辽流域年平均气温为3~8°C，年均相对湿度为50~75%。与此同时，由于受季风的影响，全年60~80%的降水量集中分布在7月至9月期间。

根据2006年的数据统计，松辽流域有251,000 km^{2}的耕地（20.2%），566,000 km^{2}的森林（45.6%）和212,600 km^{2}的牧场（17.1%），其中耕地主要分布在松嫩平原、三江平原和辽河平原，是世界三大黑土地区之一。

松辽流域蕴含丰富的自然资源。这里既有中国最肥沃土地（黑土），也有中国最好的草原和森林，还有各种各样的矿产资源，石油和煤炭储备分别占全国的50%和10%。

截至2003年，黄河流域有0.6295亿农村人口和0.5605亿城镇人口，总数占全国总人口的9.2%。在该流域内，平均人口密度超过95人/km^2，仅为全国平均水平的70%。同年，松辽流域GDP为13625亿人民币，占全国GDP总量的11.6%。

松辽流域是中国水资源最丰富的地区之一，水资源总量约为1990亿m^3。1956~2000年多年平均降水量是515 mm，约合6,432亿m^{3}的总水量，仅为全国多年平均降水量的57.2%。其中，松花江流域多年平均降水量为505 mm，辽河流域为545 mm，分别约合4,791亿m^{3}和1,713亿m^{3}的总水量。1956~2000年多年平均地表径流为1,704亿m^3，其中松花江流域占75.8%，辽河流域占24.2%。同期年均地下水资源为680亿m^3，其中松花江流域占70.3%，辽河流域占29.7%。松辽流域水资源的时空分布很不平衡，尤其在空间上，大部分水资源分布在流域周围而中西部地区较少。

1999~2004年，松辽流域年均供水量为583.4亿m^3，其中320.3亿m^{3}来自地表水供应、263.1亿m^{3}来自地下水供应。与全国平均水平（20%），长江流域（4.75%）和黄河流域（35.6%）相比，松辽流域地下水开发利用率最高，达46.6%。然而，更糟糕的是，近年来地下水资源过度开发的现象仍然十分严重。同一时期，松辽流域年均用水量为579.8亿m^3，包括70.6%农业用水、21.0%工业用水和8.4%的生活用水。由于水资源空间分布不平衡，该流域仍有50%的农村人口受到无法得到安全应用水供应的威胁。

松辽流域拥有中国最多最大的湿地，总面积达106,069 km^2，占流域总面积的8.5%。由于松辽流域植被覆盖率较高，较少发生水土流失，因此水体中含沙量较低。不过，在辽河流域，受干旱、高土地开发率和低植被覆盖率等因素的影响，导致该亚流域土壤侵蚀严重和河流含沙量高。

作为困扰老工业基地的问题之一，松辽流域污水排放量巨大且处理率很低，这使得地表水质恶化严重。2002年，有63亿吨污水被排放入河流中，占水资源总量的4.58%，是全国平均水平的1.6倍。

1999~2004年间，松辽流域水资源利用效率虽然呈持续上升，但水平仍然很低，单位GDP用水量仅为3.03美元/m^3，远低于2004年世界平均水平12.05美元/m^3。

水资源供应问题的重要性，不仅关系到安全饮用水，而且关系到安全卫生。根据2005年的统计数据，松辽流域农村地区卫生厕所平均覆盖率仅为51.3%，人类粪便无害化平均处理率仅为57.3%。

松辽流域有许多国际河流，但由于这些河流水资源利用开发率相对较低，因此，这并没有成为该流域所关注的问题。松辽流域覆盖面积广，且有着错综复杂的水系，所以，在流域内不同地区的水资源利用冲突仍然是水资源管理中的一个关键问题。

3.1.4 Orkhon河流域

Orkhon河是蒙古中部最重要的河流之一，全长1,124 km，落差1,979 m。Orkhon河流域总面积83,012 km^2，占蒙古国土总面积的约5.3%。

Orkhon河流域主要可分成两个地形区域：①上游为崎岖陡峭的山地，其中最高海拔为Khangai山脉，3,179 m；②下游为河谷，平均海拔1,200~1,400 m。

Orkhon河流域属于大陆性气候，其特点是降水量低而蒸发量高，年均气温为2.3°C。与此同时，由于受蒙古反气旋的影响，全年约70%的降水量集中分布在7月至8月期间。

根据2002年的数据统计，Orkhon河流域有3,616 km^2的耕地（4.4%），24,738 km^2的森林（29.8%）和48,569 km^2的牧场（58.6%）。由此可见，牧场是Orkhon河流域首要的土地利用类型。

截至2005年，Orkhon河流域有34.494万人口，占全国总人口的13.9%。在该流域内，平均人口密度仅约4人/km^2，几乎是东北亚地区平均水平的0.88%。因此，Orkhon河流域是世界上人口最稀疏的地区之一。同年，Orkhon河流域GDP4,170.7亿为图格里克，占全国GDP总量的10.2%。

Orkhon河流域水资源总量约为50.6亿m^3。1940~2004年多年平均降水量是307.4 mm，约合255.2亿m^3的总水量，是全国多年平均降水量的1.7倍。由此表明，Orkhon河流域是蒙古降水量丰富的地区。1945~2004年多年平均地表径流为45亿m^3，同期年均地下水资源为13.2亿m^3。由于相对较低的人口密度，Orkhon河流域人均水资源量为16,338.7 m^3，约为世界安全水平的9~10倍。

1996~2002年，Orkhon河流域年均供水量为0.96亿m^3。同期内，Orkhon河流域年均用水量为0.2043亿m^3其中包括20%农业用水、54%工业用水和23%的生活用水。目前，Orkhon河

流域水质依然处于优良水平，其中75%属于I、II类水质，25%属于III类水质。

近年来，由于过度放牧和灌溉，Orkhon河流域的一些泉和湖泊正在逐步萎缩，甚至消失。与此同时，从1985年起由于发展采矿业和从砂砾层中提取硝酸和磷等物质，导致下游水污染日趋严重。

3.1.5 Tuul河流域

Tuul河是蒙古中部最重要的河流之一，自西向东流，全长704 km。Tuul河流域总面积49,841 km^2，占蒙古国土总面积的约3.2%。

Tuul河流域主要可分成两个地形区域：①上游为崎岖陡峭的山地，其中最高海拔为Khentei山脉，2,000 m；②下游为覆盖森林和大草原的丘陵和平原。

Tuul河流域属于大陆性气候，其特点是降水量低而蒸发量高，年均气温为-4.8°C。与此同时，由于受蒙古反气旋的影响，全年约80～90%的降水量集中分布在7月至8月期间。

根据2002年的数据统计，Orkhon河流域有727 km^2的耕地（1.5%），1,447 km^2的森林（2.9%）和40,016 km^2的牧场（80.2%）。由此可见，牧场是Tuul河流域首要的土地利用类型。

截至2000年，Tuul河流域有87.1815万人口，占全国总人口的36.7%。在该流域内，平均人口密度约为18人/km^2，几乎是东北亚地区平均水平的7.93%。因此，Tuul河流域是世界上人口最稀疏的地区之一。同年，Orkhon河流域GDP 12,729亿为图格里克，占全国GDP总量的31.1%。

Tuul河流域水资源总量约为12.8亿m^3。1940～2004年多年平均降水量是284.7 mm，约合141.9亿m^3的总水量，是全国多年平均降水量的1.6倍。由此表明，Tuul河流域是蒙古降水量丰富的地区。然而，Tuul河流域年均蒸发量也很大，约为800～900 mm，是其降水量的2.8倍。1940～2004年多年平均地表径流为10.2亿m^3，同期年均地下水资源为2.5亿m^3。由于相对较低的人口密度，Tuul河流域人均水资源量为1,468.2 m^3，几乎正好与世界安全水平持平。

1997～2004年，Tuul河流域年均供水量为0.5811亿m^3，其中约95%来自地下水供应。同期内，Tuul河流域年均用水量为0.5343亿m^3，其中包括9.1%农业用水、50%工业用水和40.9%的生活用水，并且牲畜用水在农业用水量中占了最主要的部分。

Tuul河流域共有84条河溪、58个湖泊和106个泉。然而，随着过度放牧等人类活动的剧烈影响，在过去的10年中，有8条河流、8个湖泊和16个泉相继干涸消失。

1990~2000年是蒙古向市场经济转型的时期。在这期间，众多私人工厂纷纷建立起来。大约60%的废水用泵抽取处理，但其中只有40%的废水会通过物理、化学和生物等手段，而其余的废水则被直接排放到河流中。虽然，Tuul河流域目前上游水质还保持在II类的标准，但下游水质已恶化至V类水平。

3.2 选定流域综合分析

基于上述东北亚地区选定的5个流域所体现的共同问题，有关水资源脆弱性深入评估的综合分析将在本节中的以下4个方面上得以体现，即水资源基本状况、水资源开发与利用、水资源生态健康和水资源管理（表3.1）。

表3.1 淡水资源脆弱性评估框架

Table 3.1 Framework for in–depth vulnerability assessment of freshwater resources

东北亚地区淡水资源的主要问题	
水资源基本状况	→ 水资源短缺 → 水资源时空变化
水资源开发与利用	→ 水资源利用压力 → 可利用的改善的水资源供应
水资源生态健康	→ 生态系统恶化 → 水体污染
水资源管理	→ 水资源利用效率 → 可利用的改善的卫生设施 → 管理冲突

3.2.1 水资源基本状况

我们关注水资源，是因为它在为人们的生活、区域经济发展和生态健康提供基本保障上起着不可或缺的作用。然而，不容乐观的是，东北亚地区水资源总量约为12,936.4亿m^3，人均水资源量约为1272,07 m^3，只有世界平均水平的约14.7%，已成为世界水资源最贫乏的地区之一。

决定一个地区水资源基本状况的主要因素，除了该地区特有的地理位置和其他一些能够影响其降水量分布的自然因素外，那就是气候变化。包括全球变暖在内的气候变化，能够导致一个地区大气降水量与水体蒸发量、土壤水分蒸发蒸腾损失总量之间的不平衡以及植被类型分布和覆盖程度的差异。东北亚地区拥有3种气候类型和5种地形类型，因此全部4种干湿状况分布在该地区都有体现。一方面，半湿润区、半干旱区和干旱区的大气降水量和河流径流量都呈逐年减少的趋势，但减少的幅度则较快增长，地表水资源贫乏的状况日益严重，其最明显的表征为河流断流。以黄河流域为例，据黄河1919年以来水文观测资料统计，黄河自然断流始于1972年，1987年后几乎连年出现断流，进入20世纪90年代其断流时间不断提前，断流范围不断扩大，断流频次、历时不断增加（图3.1）。

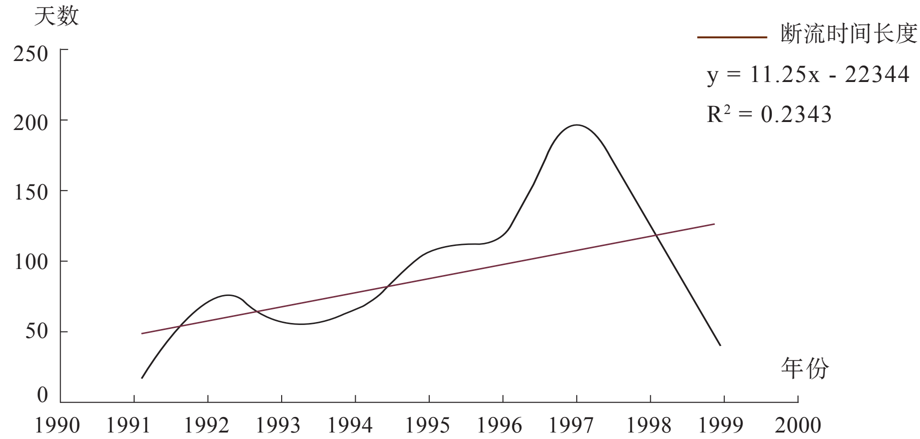

图3.1 利津水文站所观测到的黄河断流的天数

Fig. 3.1 Cut–off duration of Huanghe River observed at Lijin hydrological station (Che and Wang, 2002)

与此同时，随着东北亚地区人口膨胀和城市化进程的迅猛发展，出现了一些不容忽视的社会经济问题，比如，城市人口密度过大，城市规划不科学、不合理，产业结构未进行因地制宜地调整优化等，这给本已脆弱的地表水资源增添了沉重的负担。正是因为这样，导致了人类活动进一步转向地下水资源的索取，从而使得地下水资源也同样受到日益枯竭的威胁，其最明显的表征为地下水位下降。以Tuul河流域为例，蒙古首都乌兰巴托市1998年的地下水位已降至3.1 m，约为1948年的2倍深，并且这种下降的趋势仍在逐年增加之中（图3.2）。

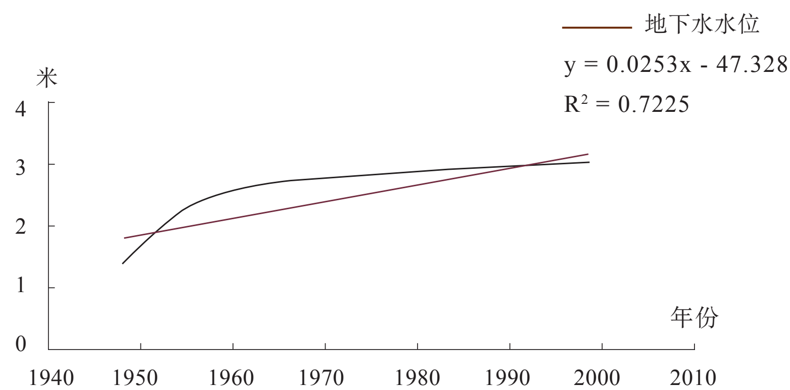

图3.2 Tuul河流域乌兰巴托市地下水位变化情况

Fig. 3.2 Groundwater table in Ulaanbaatar in the TRB

另一方面，东北亚地区湿润区的大气降水量和河流径流量则呈增大的趋势，尤其是近10年来，增大的幅度有所加快，并且表现出显著的受季风影响的时间性，即①全年降水量的70～80%集中在6～9月；②全年强降水天气集中在6～9月。因此，地表水资源时间性泛滥的状况日益严重，其最明显的表征为洪水。以长江流域为例，从1960～2002年间，长江流域夏季降水量和夏季强降水天气出现频率均呈显著增长的趋势（图3.3、图3.4）。

此外，洪水发生频率和持续时间也因受强烈的人类活动影响而变得恶化。首先，植被破坏导致水土流失；其次，土地过度开垦和盐碱化使得湖泊面积萎缩；第三，防洪堤的建造让河床和河谷淤积。

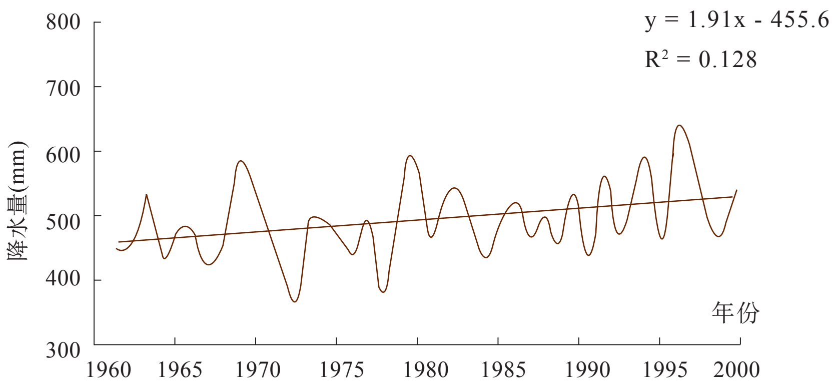

图3.3 长江夏季降水量

Fig. 3.3 Summer precipitation of Changjiang River
(Su et al., 2005)

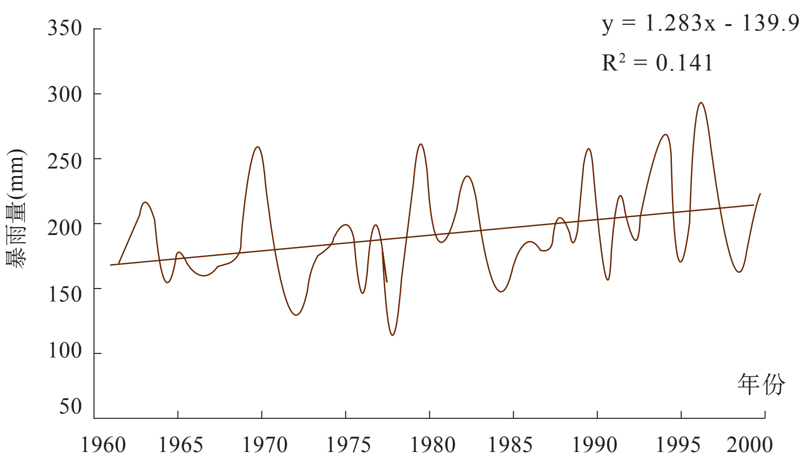

图3.4 长江夏季强降水天气出现频率

Fig. 3.4 Summer rainstorm magnitude of Changjiang River
(Su et al., 2005)

水资源短缺和旱涝灾害频发，不仅减少了东北亚地区的农作物产量，制约了第二、第三产业的蓬勃发展，同时，还加重了该地区贫困人口和失业人口的比例和对生态系统的污染和破坏，在较大程度上，对东北亚地区经济繁荣、社会稳定、生态和谐的可持续发展造成了消极的影响。目前，东北亚地区的各国政府都十分重视和关注水资源短缺和旱涝灾害频发这2个关键问题，纷纷通过立法、组建专门管理结构、加大民众宣传力度等多种形式来缓解和改善水资源脆弱性的现状。

3.2.2 水资源开发与利用

东北亚地区是世界上用水紧张的地区之一，用水总量约占世界的12.5%，而人均用水量则约为世界平均水平的76%。其中，农业用水占了最大比例，约为总量的60%。据不完全统计，90%以上的农业用水集中于农业灌溉用水，而东北亚地区又是世界上农业灌溉面积最大最集中的地区之一（图3.5）。但令人不安的是，东北亚地区仍主要采用漫灌这样粗放型的灌溉方式，其水资源的利用效率据估算仅为25%。

东北亚地区人口密度约为128人/km^2，城市人口率约为42%，是世界上人口最为稠密和城市人口较为集中的地区之一。从图3.6中可以发现，与1990年相比，东北亚地区2002年的人口密度和城市人口率分别增长了11.3%和41.5%。同时，一个国家的经济水平和城市化程度越高，城市人口生活用水量就越大。据联合国科教文组织（UNESCO）2000年推算，发达国家平均每人每天用水在500～800 L（约合300 m^3/年），而相比之下，发展中国家平均每人每天用水则只有150 L（约合20 m^3/年）。因此，水资源的过度开发利用给东北亚地区的社会经济发展和生态系统健康所造成的制约影响已变得日益凸现。

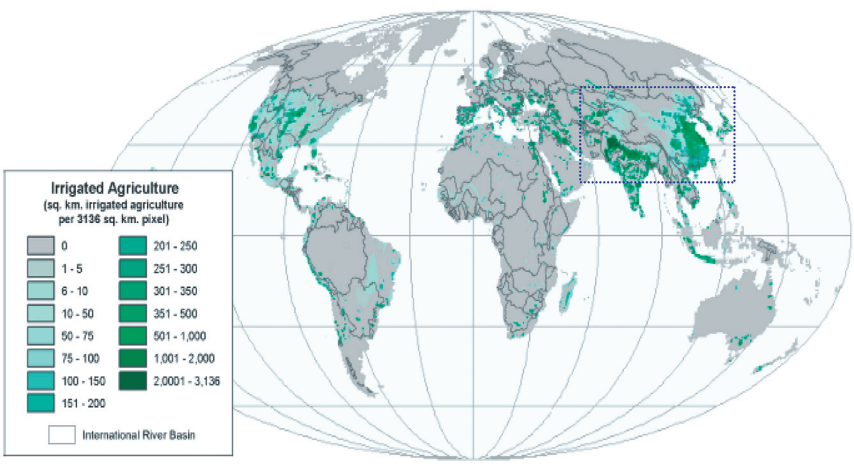

图3.5 东北亚地区1995年左右的灌溉面积（蓝色虚线矩形）

Fig. 3.5 Irrigated areas circa 1995 in Northeast Asia sub−region (blue dash rectangle)
(UNEP, 2002A)

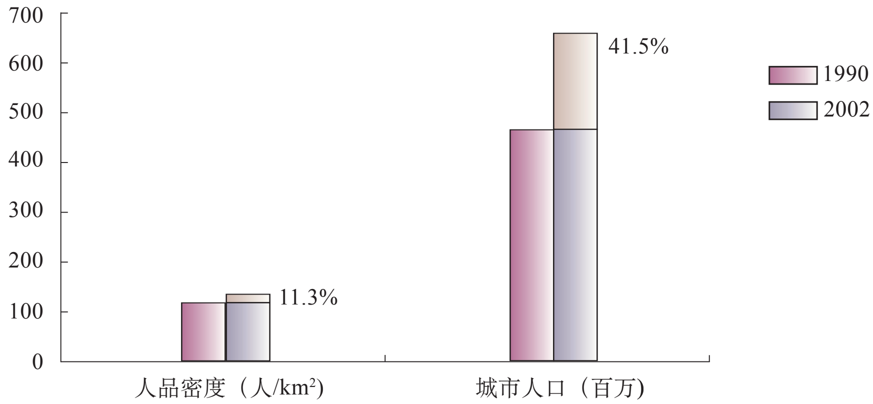

图3.6 东北亚地区人口密度和城市人口变化

Fig. 3.6 Variation of population density and urban population in Northeast Asia sub-region (ADB, 2006)

过度抽取地下水易造成地面沉降和凹陷，特别是在城市地区，这种状况更为严重。由于城市人口密度大，使得土地资源稀缺，因此，城市地区的地下空间利用率较高，例如地下车库、地下商场、地下体育馆等，而这些地下“空洞”则进一步加剧了地面沉降的速度。据统计，由于长江三角洲地面沉降所造成的经济损失高达3,500亿人民币。

对于过度开采水资源的响应大多都集中在如何减轻地区农业用地压力的问题上。例如，中国政府已经发起了几个国家重点项目来调整土地利用结构。其中，全国性的“耕地保护”项目就是一个典型，其目的在于通过对所有的陡坡农田实行退耕还林、退耕还草来恢复退化的土地。

由于受水资源总量和水体质量的影响，东北亚地区有很大的一部分人口无法得到改善的饮用水供应，约占世界水平的1/3。在城市地区，截至2002年，有93.7%人口能够得到改善的饮用水供应，然而，该地区的水污染既大大增加了处理废水的费用，也提高了水价。在农村地区，状况更加糟糕。截至2002年，只有70.1%人口能够得到改善的饮用水供应，同时超过一半数量的大牲畜无法得到足够的饮用水（ABD, 2006）。此外，由于受特殊的地理和地质因素的影响，一些农村地区的天然水体中，尤其是在地下水，含有高难度（通常高于正常标准）的碘、氟、砷等，这也给改善的饮用水供应带来了威胁。

在选定5个流域中，改善的饮用水供应面临两种不同的压力。在城市地区，水污染使得供水压力增大且废水处理效率降低。以黄河流域为例，2000年废水排放总量为42.67亿m^3，几乎是1980年的2倍，从而导致70%饮用水源供应被严重污染，其水质大多属于V类或劣V类水平。在农村地区，相对严重的是供水基础设施和镇村供水服务都很落后。

自1995年以来，千年发展目标推出了一项特别计划，主要反映了国际社会共同努力来减少

全球贫困所作出的承诺。其中，千年发展目标的分目标10就是要在2015年前将全球无法得到改善饮用水供应的人口数量比例减少一半。

3.2.3 水资源生态健康

在过去的十年中，东北亚地区湖泊和湿地退化严重。根据2003年蒙古的水调查，Orkhon河流域已有12.3%的湖泊和31.5%的泉干涸了（图3.7）。相比20世纪50年代的遥感数据，2000年松辽流域的松花江亚流域的湿地面积已经减少了2.61万km^2，下降速度十分惊人（图3.8）。

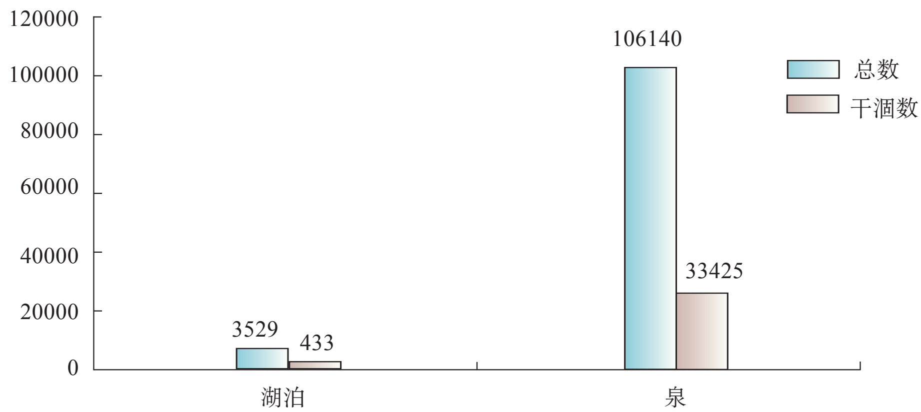

图3.7 Orkhon河流域湖泊和泉的数量变化

Fig. 3.7 Quantity variation of lake and springs in the ORB

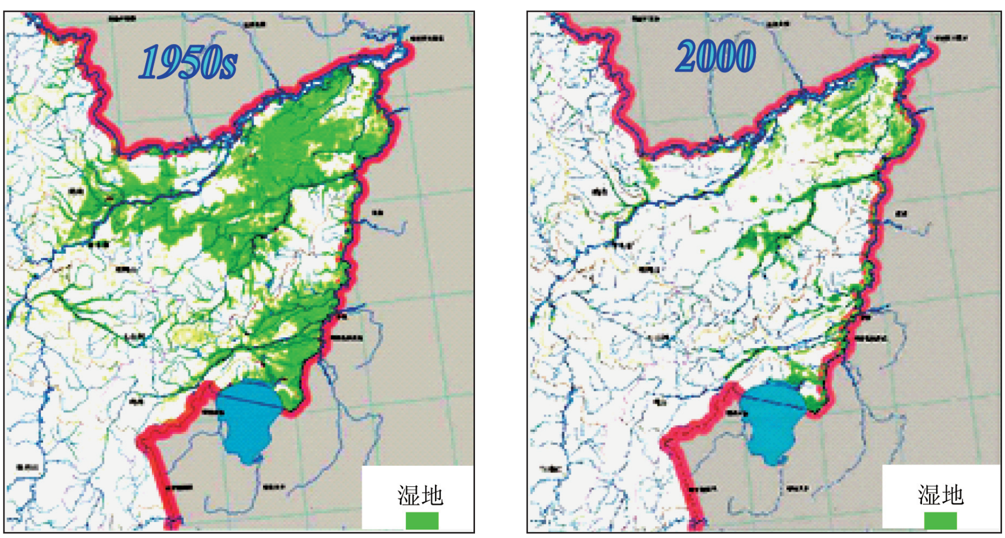

图3.8 松辽流域松花江亚流域的湿地分布变化

Fig. 3.8 Distribution changes of wetland in SHJRB of the SLB

在东北亚大部分地区，发展经济是大多数地方政府办事议程的第一要务。随着20世纪80年代中国实行的改革开放政策和20世纪90年代蒙古向市场经济转型，水资源的需求量急剧增加。对于水资源的过度开发，使得土地退化和水土流失愈发严重。在Orkhon河流域，目前已有超过70家金矿开采的企业，他们任意改变河流的走向。在黄河流域，水土流失产生了16亿t泥沙。此外，由于近年来气候变化趋向干旱，使得温度不断上升，而降水则持续减少，损害了东北亚地区水资源的生态健康和可持续发展。

随着湖泊和湿地的不断萎缩，动植物的栖息地正在逐渐消失，从而导致东北亚地区生物多样性的丧失。据统计，许多特有的濒危物种，像鱼类、两栖类、水禽、水生哺乳动物等正面临灭绝的威胁。例如，白鳍豚（*Lipotes vexillifer Miller*）是一种长江流域特有的著名的水生哺乳动物，截至1995年，它的种群数量已经迅速减少至不足100头（图3.9）。

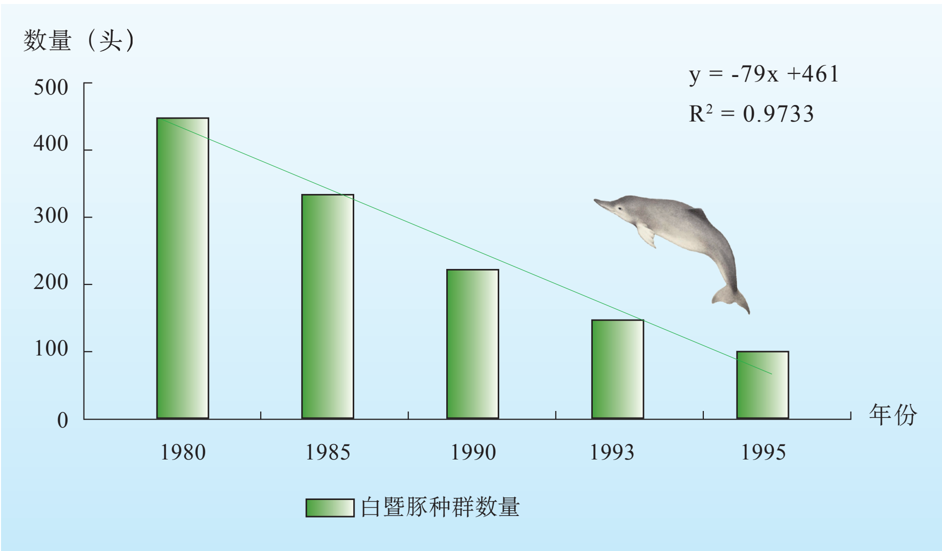

图3.9 长江白鳍豚种群数量变化

Fig. 3.9 Population variation of Yangtze River dolphin (Lipotes vexillifer Miller)

东北亚地区水体质量整体呈下降趋势，恶化现象十分严重。其一，蒙古素以畜牧业为国民经济支柱产业，因此水体受工业污染很少，水质始终保持在I类~III类水的水平，其中以I类水和II类水居多。然而，近年来许多私营小工厂如雨后春笋般建立起来，并且通常都依河而筑。他们不仅消耗大量的水资源，而且还向河道中直排未经任何处理的生产废水。在Tuul河流域下游Songino处水质因此已降至V类水。其二，目前中国向河道中倾泻的工业废水和污泥每年仍能达几十亿吨，尽管近年来排放总量始终呈递减的趋势。因此，这就导致了中国水质依旧在继续地恶化（图3.10）。

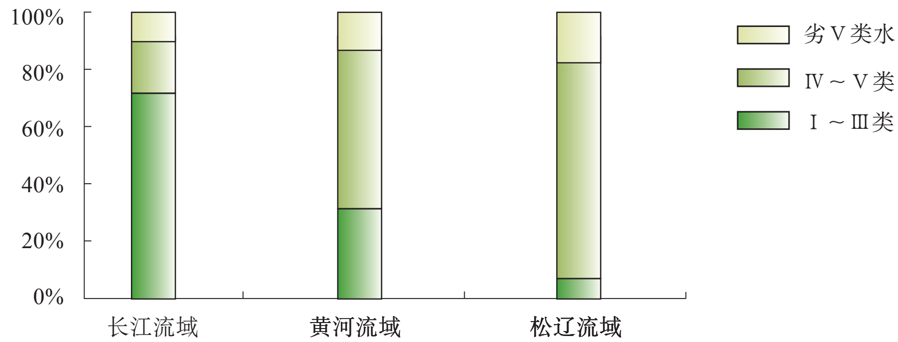

图3.10 长江流域、黄河流域和松辽流域水质分类（2003）

Fig. 3.10 Category of water quality in CRB, HRB, and SLB (2003) (GOVCN–G)

水污染的压力来自以下几个方面：①人口膨胀，②迅猛的经济发展，③不合理的产业结构，④废水和污泥设备投资过少。工业发展是基于低技术要求和高资源能耗的企业增长。一些重污染的小规模制造企业，例如，造纸、化学制药、食品加工、金属加工、皮革加工、印刷和玻璃制造等，雨后春笋般建立起来。然而，这些企业并不关心如何处理大量的废水与污泥和水污染的问题，而只关注于所得利润的多少。

水污染使水资源短缺的状态每况愈下，严重影响农业、工业和生活供水，对人体健康和水生生态系统的生物多样性造成损害。此外，水污染在加剧经济损失的同时，还制约了经济、社会和生态环境的可持续循环发展。

东北亚地区的各级政府都在千方百计地改善水质。在中国，有关环境污染预警和控制的重点项目已被编入第11个“5年计划”，其中涵盖了长江上游地区、黄河流域、松花江流域和三峡库区等关键地区。同时，这些项目还突出了南水北调工程沿线的水源地和水路通道地区。

3.2.4 水资源管理

一般而言，作为指示用水效率的一个非常重要的指标，单位GDP用水量反映了政府部门在节水和环境保护上所取得的成绩。东北亚地区单位GDP用水量约为世界平均水平的35%，是世界上用水效率最低的地区之一。在农业方面，仍主要采用漫灌这样粗放型的灌溉方式，一般浪费水量达75%，并大多通过地表蒸发或地下渗漏的形式所丧失。在工业方面，用水效率偏低的主要原因在于陈旧的供水设备系统和落后的节水技术。在生活方面，则表现为家庭节水器具普及不广，家庭循环用水次数不多，住宅区中水循环设施配备不足、使用不勤、管理不利。

水资源已长期被视为“免费资源”，同时，对于水资源价值整体发展缺少认识都充分体现在了不同层面的水资源管理政策上。由于在政策层面上缺乏适当的估价机制，在现行的政策

框架下，水资源利用不能得到有效地控制。因此，水资源价格无法得到合理地确定，并且通常还被严重低估。在这种低估的驱使下，其直接压力就来自于所有利益相关者，包括政府和企业，对于节水设施建设和技术发展研究的低投入。

由于用水效率低下，水资源短缺和水污染的问题就变得日益尖锐。如上所述，约70%水可能在运输途中损失。然而，增加节水设施和用水管理的投入将使水资源利用效率提高一倍。

在中国，对用水效率低下的响应主要来自两个方面。其一，在中央政府科学发展观的方针指导下，有关水资源保护和利用效率改进的一系列政策处于高度优先的位置。其二，水务部门对于研发的投入迅速增加。2000～2005年期间，一个名为“现代农业节水技术体系及新产品”的独立研发项目，能够大大提高灌溉的用水效率，已在科研院所中取得了实践。

受水资源短缺和水污染的影响，东北亚地区有大量人口还无法得到改善的卫生设施，几乎是无法得到改善饮用水供应的2.3倍。生活在这样的条件下，对于个人健康和环境健康都构成了高风险。在城市地区，截至2002年，有62.3%的人口能得到改善的卫生设施，但在农村地区却仅有32.5%的人口能够得到改善的卫生设施。不过，与1990年的状况相比，东北亚地区已有1.5亿城市人口和1.77亿农村人口从中受益。

供水系统对于安全饮用水和安全卫生设施都十分重要的。卫生厕所的建设取决于自来水供水系统。1995～2005年期间，长江流域农村地区的自来水供水系统覆盖率从46.3%稳步增长至65.3%。然而，目前在东北亚地区仍有将近一半的人口无法得到自来供水系统和基本的卫生设施（MH of PRC, 1996～2006）。

4 脆弱性指数与结论

作为淡水资源脆弱性评估的一个重要的组成部分，综合脆弱性指数系统（VIS）能够根据所考虑的主要因素在评估的实际应用，来阐明流域的基本状况。对于脆弱性指数系统的具体解释详见方法论（Huang & Cai, 2008）。

表4.1列出了东北亚地区选定5个流域的脆弱性指数。根据方法论，脆弱性指数及其9个指标用不同的颜色来表示其脆弱性的程度，即低、中度、高和严重。

表4.1 东北亚地区选定5个流域的脆弱性指数

Table 4.1 Vulnerability Indexes of 5 selected river basins in Northeast Asia sub–region

	水资源匮乏 (RSs)	水资源变化 (RSv)	水需求压力 (DPs)	安全饮用水可获得性 (DPd)	水污染 (EHp)	生态退化 (EHe)	用水效率 (MCe)	改进的卫生设施 (MCs)	管理能力 (MCc)	脆弱性指数 (VI)
CRB	0.000	0.225	0.195	0.145	0.174	0.395	0.929	0.145	0.400	0.264
	0.113		0.169		0.286		0.491			
SLB	0.128	0.740	0.330	0.182	0.231	0.370	0.937	0.229	0.290	0.369
	0.434		0.256		0.300		0.486			
HRB	0.684	0.347	0.656	0.250	0.680	0.520	0.995	0.250	0.400	0.529
	0.516		0.453		0.600		0.548			
TRB	0.255	0.554	0.041	0.379	0.420	0.829	0.657	0.574	0.340	0.441
	0.405		0.210		0.625		0.524			
ORB	0.000	0.515	0.022	0.827	0.073	0.073	0.956	0.952	0.420	0.383
	0.257		0.428		0.073		0.776			

低	中度	高	严重

分析结果如下：

[1] 选定五个流域的脆弱性级别为“中度”或“高”两个级别，改善水资源状态急需水资源管理的介入；

[2] 总体而言，除了长江流域属于湿润和半湿润地区，Orkhon河流域人口密度非常低外，其

他流域在水资源基本状况上都存在较大问题，主要表现为干旱且人均水资源量较低。同时，这些流域还遭受年内水资源量不稳定交换的影响。例如，松辽流域年均降水量的严重分布不均，加大了水资源可持续管理上的难度。

[3] 水资源开发和利用方面，在水资源短缺的流域，其水资源开发速度通常很高，黄河流域就是典型，其水资源开发速度达到65%。尽管其他流域没有达到红色警告线，然而持续的人口膨胀和城市化发展需要越来越多的集中供水，使其同样面临着巨大的挑战。另外，水资源的过度开发（包括地表水和地下水两个方面）将严重地影响水文过程的健康，使得流域面临高生态风险。

[4] 生态健康方面，根据目前的数据资料，由于东北亚地区持续的水质恶化，使得该地区中大多数流域，即使是那些脆弱性程度很低的流域，都存在生态风险。另外，也可以从另一个指标——植被（含湿地）覆盖率中看出。在这5个选定流域中，植被覆盖率越低，生态恢复的难度就越大。

[5] 管理能力方面，5个流域之间有着较大的差别。一个普遍的问题是用水效率较低。尽管大多数的流域都面临供水短缺的问题，但受众多与水资源管理能力相关因素（包括技术和政策）的影响，用水效率依然十分低。

[6] 对于那些拥有国际河流的国家来说，管理冲突是另一项重要指标。尽管这五条河不全是国际河流，但它们流域面积大，都存在不同等级的跨行政区管理问题。在中国，这3个流域的管理制度相似，但仍然存在一些管理能力上的差异。蒙古2个流域也存在类似状况。

政策建议：根据上述分析，应考虑采用以下政策建议来改善未来的水资源管理。

[1] 改善用水效率：尽管这5个流域大部分位于半干旱和干旱地区，并且水资源短缺，然而其用水效率依然非常低。对于用水效率有显著影响的因素主要有2个，分别是发展政策和技术投入。在东北亚地区，农业用水占了主导的地位，但是农业用水效率却比其他产业都要低。因此，农业的发展政策需要重新评估，相关政策应该出台以改善农业用水效率，包括优化农业生产结构和水价经济政策。用水效率的提高同样需要较高的技术支持，例如，节水技术的发展。在东北亚地区，对于水资源管理的技术研发投入还相对较低，这应作为国家重要技术改革议程的重要一节。

[2] 综合全面的流域管理：目前的管理计划是以政策行政系统为基础的，它在协调统一河流各河段方面表现很弱。流域各部分都有其独特之处，并在流域生态系统中起着不同的作用。目前的中央管理系统使得流域各部分交叉协作能力变得十分有限。因此，为了加强流域尺度的管理制度，应该将管理权下放到各个地方政府。同时，流域管理的关键就在于应该鼓励所有利益相关方的共同参与。此外，流域管理系统的另一个重要作用在于通过

水资源分配的协调机制来确保水资源的合理利用。

[3] 环境保护和污染控制：在5个选定流域中，除Orkhon河流域在污染控制和植被覆盖等方面都有着较好的生态状态外，其余4个流域都处于严重的环境恶化的威胁之中。环境保护对于恢复退化的生态系统起着非常重要的作用，其手段应包括以确保足够的生态流量的水土侵蚀控制和水土流失控制，以及控制污染物排放的污染控制。

[4] 减轻贫困和安全饮用水供应：在今后很长一段时间，减轻贫困是综合流域管理的重要发展任务。贫困人口的基本需求应被优先考虑，包括安全饮用水供应、可选择的生活环境和通过参与水资源管理来改善当地人民解决相关实际问题的能力。

参考文献

- ADB (Asian Development Bank), 2006. Asia Water Watch 2015 – Are countries in Asia on Track to Meet Target 10 of the Millennium Development Goals?
- Baldandorj, T., 2005. Water management for Mongolia.
- Chandmani, D., 2005. Water amelioration, 101—103.
- Che, Z.X., Wang, Q.Z., 2002. Cause and Countermeasure of the Huanghe River Cut-off. Journal of Shandong Meteorology, 04: 11—13.
- Davaa, G., Myagmarjav, B., 1975, 1999. Surface Water of Mongolia, 1.13—1.35, 9.1—9.15.
- FAO-SDRN-Agrometeorology Group, 1997. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/atmospheric_moisture/geographic_patterns_equator_subtropics.html.
- Huang, Y., Cai, M.T., 2008. Methodological Guidelines for Vulnerability of Freshwater Resourus to Environmental Change in Asia ISBN:978-92-807-2953-5, Job Number: DEW/1106/BA.
- IMF (International Monetary Fund) http://www.imf.org/external/pubs/ft/weo/2007/01/data/index.aspx.
- MFA of PRC (Ministry of Foreign Affairs of People's Republic of China):
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1221/1221x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1236/1236x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1261/1261x0/default.htm;
  http://www.mfa.gov.cn/chn/wjb/zzjg/yzs/gjlb/1281/1281x0/default.htm.
- MH of PRC (Ministry of Health of People's Republic of China), Statistics Yearbook Abstract 1996-2006.
  http://www.moh.gov.cn/menunews/C30302.htm.
- MSY (Mongolian Statistics Yearbook), 2005, 2006.
- CSY (China Statistics Yearbook), 2006. National Bureau of Statistics of China. http://www.stats.gov.cn/tjsj/ndsj.
- Scientific Survey Reports of Orkhon and Tuul River Basin. 2005, 2006.
- Statistic Book of Nature and Environment, 2000.
- Su, B.D., Jiang, T., Jin, W.B., 2006. Recent trends in observed temperature and precipitation extremes in the Yangtze /river basin, China. Theor Appl Climatol, 83: 139—151.
- GOVCN (Central People's Government of People's Republic of China):
  A: http://www.gov.cn/test/2005-08/11/content_27116.htm;
  B: http://www.gov.cn/test/2005-07/27/content_17402.htm;
  C: http://www.gov.cn/test/2005-06/24/content_17362.htm;
  D: http://www.gov.cn/test/2005-07/27/content_17405.htm;
  E: http://www.gov.cn/test/2006-04/04/content_244533.htm;
  F: http://www.gov.cn/test/2005-07/27/content_17403.htm;
  G: http://www.gov.cn/test/2005-07/27/content_17758.htm.

- UNEP, 2002A. Atlas of International Freshwater Agreements. http://www.transboundarywaters.orst.edu.
- UNEP, 2002B. Vital Water Graphics – An Overview of the State of the World's Fresh and Marine Waters.
- WB (World Bank) http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html.
- Xinhuanet:
  http://news.xinhuanet.com/ziliao/2002-04/01/content_329931.htm;
  http://news.xinhuanet.com/ziliao/2002-06/13/content_438328.htm;
  http://news.xinhuanet.com/ziliao/2002-06/18/content_445580.htm;
  http://news.xinhuanet.com/ziliao/2002-06/18/content_445618.htm;
  http://news.xinhuanet.com/ziliao/2002-07/04/content_469910.htm.
- Zhao, S.J., Fang, S., Miao, B., Gu, S., Tao, C., Peng, Z., 2004. The seven-decade degradation of a large freshwater lake in central Yangtze River, China. Environmental Science and Technology,39: 431—436.

术语表

- 权限：使用权表示某个人或者集体占有或使用水资源，或者使用水资源提供不同用途的服务权利。
- 适应：社会或者生态系统应对水资源压力的过程，也表示社会或者生态系统解决它们水资源脆弱性的能力。
- 冲突管理能力参数：用于指示流域管理系统应对跨流域冲突能力的参数。一个管理系统的好坏基于其制度安排效率、政策制定、交流机制和执行效果。
- 生活用水：包括饮用水与家庭用水，市政、商业建设和公共服务（例如，医院）。
- 生态健康：即流域的生态系统健康。较低的废水排放和较高的植被覆盖反映了一个流域较好的生态健康。
- 生态用水：所有生态系统都需要水来维持其生态过程和生物群落。环境水需求是指以低风险维持水源依赖型生态系统既有价值所需的水域。
- 生态系统退化参数：用没有植被覆盖（林地和湿地）的土地比例来表征生态系统退化对水资源脆弱性的影响。
- 淡水：适于人类和大部分陆地动植物所利用的那部分水资源，是一种从降雨形成地面径流流向地表水、地下水和土壤保持的可再生水资源。本文中所提及的"水"和"淡水"是同义的。
- 地下水生成：流域内或国界内由内部降水和地表径流形成的进入含水土层的总水量。
- 改进的卫生设施：卫生设施将人类的排泄物与动物、昆虫分开，包括下水道系统、化粪池，冲水公厕和便捷水龙头等。
- 改进的卫生设施可获得性参数：可以用来典型地衡量管理系统处理居住者生活需要的能力，用获得改进卫生设施的人口比例来表示。
- 指标：一个参数或者从参数计算出的数值，用来表示一个研究现象、环境或其他任何考察对象的状态信息，一般来说这个参数或指标比考察对象本身特性描述的数字更能反应研究分析中该考察对象的特性。
- 工业用水：包括机械和设备的冷却用水，产能用水，清洁用水，以及作为溶剂。
- 灌溉用水：农业中的初级用水。
- 管理能力：管理系统中处理水资源供需错配问题的能力，通过提高用水效率（单位GDP用水量）和提高人类健康状况（卫生设施可获得性）。
- 政策：政策是指导决策和行为的计划，可用于政府、私人部门组织和团体以及个人。政策过程包括识别不同的选项，譬如程序或开销优先权；基于它们可能产生的影响进行

选择。政策可以被简单地理解为为达到明确目标所实行的行政、管理、金融的机制。政策联合是协调相互影响的一系列政策。

- 安全饮用水可获得性参数：用来表示对淡水资源使用的社会适应状况，即淡水资源开发设施如何处理人口的基本生活需要。是一个反映利益相关者处理能力影响的总和参数。
- 行业用水量：表示按不同行业计算的用水量，一般包括农业、工业和生活。大多数用水量的统计都按其用途按这几个类别统计。
- 现状：用适当的结构的（河流形态学）、物理的（温度）、化学的（P、N浓度）和生物的（浮游植物和鱼类）指标来描述的状态。
- 地表水：地球表面的水资源，例如，溪水、河流、湖泊和水库。内部产生，包括内部降水产生的年均河流流量（降雨发生在流域内或国界内）。地表水资源一般通过测量或评价国家或河流流域内年总河流流量计算得到。
- 水资源总量：流域水资源总量是指可以提供维持健康生态系统和社会经济发展的淡水资源总量。
- 跨界管理：指管理跨行政边界或流域边界的水资源管理框架，包括解决冲突的管理问题。
- 脆弱性：水资源系统的弱点和缺陷的特征，使得该系统难以随着社会经济和环境的变化继续维持功能。
- 脆弱性评估：评估系统对潜在威胁敏感性的研究和分析过程，识别系统的关键问题以减少或缓解负面效应行为的风险。
- 水资源管理：开发、分配和使用水资源的计划，与先决目标一致，同时考虑水资源的量与质问题。
- 水污染参数：用以衡量流域生态健康的参数，定义为流域内未处理排放废水占水资源总量的比例。
- 水质：用以形容水的化学、物理、生物特性，通常出于对某项目适用性的考虑。
- 水资源匮乏：形容水资源供需关系的相对概念。需求可能由于不同的部门用水区别而随不同国家、不同地区而不同。有高工业需求或需要大面积灌溉的国家或流域会比不存在类似情况但具有类似气候条件的地区面临更严峻的水资源短缺问题。
- 水资源匮乏参数：水资源的丰富程度将决定其满足人口需要的程度。因此，水资源匮乏可以通过人均水资源与工人的最低人均水资源需求量（1,700 m^3/人）的比值表示。

- 水压力参数：水压力引起淡水资源的退化，包括水量（含水层过度开发、河流干涸等）和水质（富营养化、有机物质污染、盐水倒灌等）。水压力参数用水资源取水总量占流域水资源总量的比例表示。
- 用水：指所有不同用水者所使用的总水量（也包括传输过程中的损失）。根据不同的目的分为生产（农业或工业）用水、生活用水和生态环境用水。用水与人类和水循环之间相互作用和影响有关，包括几个元素，例如，从地表水或地下水获得水、向家庭或商业用途输送，水的消费，废水处理厂的排水、水回到环境、以及水系内部本身的消耗（例如，水力发电用水）。
- 用水效率：一立方米用水所产生的GDP,即单位GDP用水量。
- 用水无效参数：用来表示国家或地区的用水效率与选定国家平均用水效率之间差异所展现的水资源管理系统的缺乏效率问题。本报告中，用流域内一立方米用水产生的GDP与全球5大粮食生产国（中国、美国、墨西哥、巴西和法国）的平均用水效率间的比值表示。
- 水资源变化参数：表示水资源的变化，用过去50年的年降水量的变异系数表示。
- 水资源取水量：永久地或者暂时地从各种源头获得的用于某种用途的水资源总量。可以是向水网的分配也可以是直接地使用。包括消耗使用、运输损失和回流。水资源取水总量是农业、生活和工业生产部门的估计总用水量。