International Perspectives in Geography
AJG Library 5

Shigeko Haruyama
Takayuki Shiraiwa *Editors*

Environmental Change and the Social Response in the Amur River Basin

Springer

International Perspectives in Geography
AJG Library 5

Editor in Chief:
Noritaka Yagasaki, Japan

More information about this series at
http://www.springer.com/series/10223

Aims and Scope:

The AJG Library is published by Springer under the auspices of the Association of Japanese Geographers. This is a scholarly series of international standing. Given the multidisciplinary nature of geography, the objective of the series is to provide an invaluable source of information not only for geographers, but also for students, researchers, teachers, administrators, and professionals outside the discipline. Strong emphasis is placed on the theoretical and empirical understanding of the changing relationships between nature and human activities. The overall aim of the series is to provide readers throughout the world with stimulating and up-to-date scientific outcomes mainly by Japanese and other Asian geographers. Thus, an "Asian" flavor different from the Western way of thinking may be reflected in this series. The AJG Library will be available both in print and online via SpringerLink.

About the AJG

The Association of Japanese Geographers (AJG), founded in 1925, is one of the largest and leading organizations on geographical research in Asia and the Pacific Rim today, with around 3000 members. AJG is devoted to promoting research on various aspects of human and physical geography and contributing to academic development through exchanges of information and knowledge with relevant internal and external academic communities. Members are tackling contemporary issues such as global warming, air/water pollution, natural disasters, rapid urbanization, irregular land-use changes, and regional disparities through comprehensive investigation into the earth and its people. In addition, to make the next generation aware of these academic achievements, the members are engaged in teaching and outreach activities of spreading geographical awareness. With the recent developments and much improved international linkages, AJG launches the publication of the AJG Library series in 2012.

Editorial Board:

Shigeko Haruyama • Takayuki Shiraiwa
Editors

Environmental Change and the Social Response in the Amur River Basin

Springer

Editors
Shigeko Haruyama
Mie University
Mie
Japan

Takayuki Shiraiwa
Hokkaido University
Hokkaido
Japan

ISSN 2197-7798 ISSN 2197-7801 (electronic)
International Perspectives in Geography
ISBN 978-4-431-55244-4 ISBN 978-4-431-55245-1 (eBook)
DOI 10.1007/978-4-431-55245-1

Library of Congress Control Number: 2014956755

Springer Tokyo Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

The Amur River, or Heilongjian in Chinese, is the eighth longest river in the world. The watershed has an area of 2 million km^2 and covers the territories of Mongolia, Russia, China, and the Democratic People's Republic of Korea. In addition to its transboundary location, the Amur River Basin can be characterized by contrasts between other geographic aspects: Russia and Asia; boreal taiga and broadleaf temperate forests; continental and monsoon climates; northern and southern fauna and flora; and southern dense and northern sparse populations. The river basin was developed relatively recently and was subjected to severe political tensions throughout the nineteenth and twentieth centuries.

In 2002, we started the multidisciplinary Amur Okhotsk Project, relating the continental-scale terrestrial environment to the open-water ecosystem in the Sea of Okhotsk and western subarctic Pacific Ocean. After 8 years of multilateral effort, the project confirmed that primary production in the Sea of Okhotsk and Oyashio region depends on dissolved iron transported from the Amur River and its watershed. It is therefore reasonable to say that land use and land cover conditions in the Amur Basin are crucial for sustainable use of marine biological resources in the Sea of Okhotsk and Oyashio region.

This book features research on current and historical land use and land cover in the Amur Basin, which are important not only for basin residents but also for those affected by its material and water cycles. Land use and land cover are affected by natural and human interactions over long and short time periods. We therefore address historical and recent changes in a land cover analysis of the basin. "Amur Region of Russia: Natural Resources, Population, and Economy" is the first chapter and provides readers with background information regarding the Amur region. Chapter 2 is "Land Cover Change and Climate change Analysis of the Amur River Basin Using Remote Sensing Data", and Chap. 3 is "Wetland and Flooding in the Amur River Basin". These two chapters provide evidence of land cover change in the basin. "Changes in Wetland and Floodplain Sedimentation Processes in the Middle Reach of the Amur River Basin" is Chapter 4, which addresses the influences of land cover change on the fluvial environment from a geomorphology perspective. Land cover change, specifically the reduction of wetland, alters surface and underground water quality. Chapter 5 is "Water Chemistry of the Middle Amur

River". Chapter 6 is "Droughts in North Eurasia and Climate Warming: Regional Changes and Consequences" and describes the wide variation of climate conditions in North Eurasia, including the Amur. "Geographical Information System for the Amur River Basin" is Chap. 7, which is a fundamental land use introduction to the Amur. Individual land use change processes related to state farms in northeast China have important effects on land use change in the Amur, and these are examined in Chap. 8, "Characteristics of Irrigation and Drainage Development on the Sanjiang Plain: A Case Study of State Farms". A discussion of social factors of land use change is found in Chaps. 9 and 10, which deal with forest and timber. "Developments of Sino-Russo Timber Trade in the Amur River Basin, with Special Reference to the Transition Period During 1995–2005" is Chap. 9. "Development Process of Timber Harvesting in the Khabarovsk Region, Russian Federation" is Chap. 10. The 11th and final chapter is "Land Use Dynamics in the Amur River Basin in the Twentieth Century: Main Tendencies, Driving Forces, and Environmental Consequences".

The Amur River Basin poses an essential question: How can we manage a transboundary watershed without disturbing terrestrial and marine ecosystems for future generations? We hope that this book can provide essential information for geographers about this relatively unknown region.

Tsu, Japan — Shigeko Haruyama
Sapporo, Japan — Takayuki Shiraiwa

Contents

Chapter 1
Amur Region of Russia—Natural Resources, Population and Economy

Petre Y. Baklanov and Anatoly V. Moshkov

Abstract We present a complex assessment of the natural resources, population, and economy of the Russian Amur region, addressing the availability of certain resources and analyzing the spatial-branch structure of the economy. Correlations of individual components of natural resource capacity, population, and economic activity within the framework of the Amur transboundary territory are evaluated. This territory is a comprehensive geographic structure consisting of interacting frontier territories, and combines certain natural resources, infrastructure, settlements, and business activities within the boundaries of a major geosystem. Our approach allows the most comprehensive evaluation of the integration potential of the Amur River Basin. It determines the most effective directions for socioeconomic development of the territory, taking into account the interests of all actors in cross-border relations.

Keywords Amur region • Natural resources of Russia • Population of the Amur region • Russian economy • Socioeconomic development of Amur River Basin

1.1 Introduction

The Amur River Basin is a large geosystem, occupying an area about 2 million km^2. It includes the territories of four countries: Russia, the People's Republic of China (PRC), Mongolia, and the Democratic People's Republic of Korea (DPRK) (Table 1.1).

The Amur Basin embraces a variety of landscapes, from semi-desert, steppe and plain to forest, mountain forest, mountain taiga, and high mountains. Within the basin, there are various types of natural resources: fuel and power (petroleum, gas, coal, and hydropower), nonferrous metals, chemical raw materials, forest, water, land, fisheries, and construction materials. There is also a wide diversity of

P. Y. Baklanov (✉) · A. V. Moshkov
Pacific Geographical Institute FEBRAS, 7 Radio Street,
690041 Vladivostok, Russia
e-mail: pbaklanov@tig.dvo.ru

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_1

Table 1.1 Composition of the transboundary Amur River Basin. (Source: Baklanov and Ganzei 2008)

Country	Territory of basin part (km^2)	Share (%)
Russia	1,003,000	54.1
China	820,000	44.2
Mongolia	32,000	1.7
Democratic People's Republic of Korea	60	0.003
Whole basin	1,855,060	100

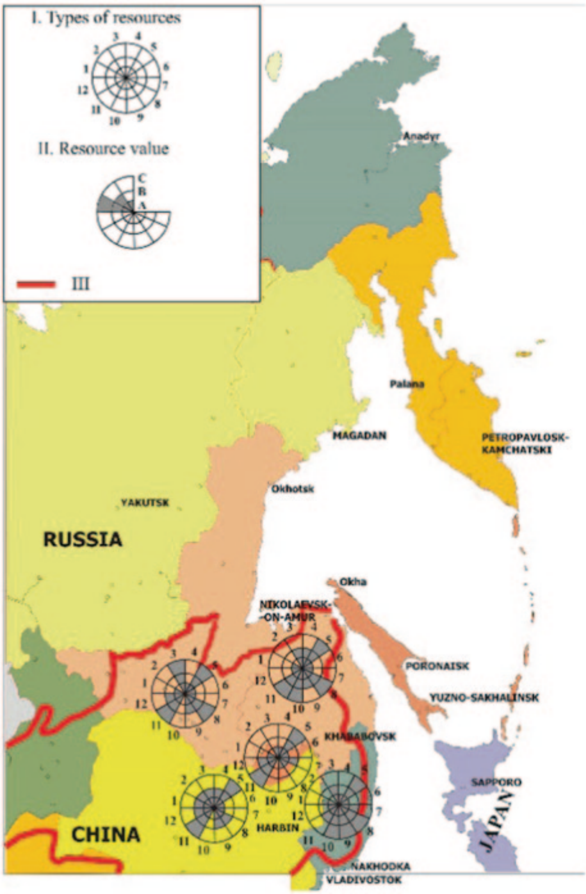


Fig. 1.1 Geographic distribution and types of natural resources in the Amur region. I. *Types of resources*: *1* coal, *2* oil and gas, *3* hydro energy, *4* ferrous metal, *5* nonferrous metal, *6* chemical raw materials, *7* non-ore raw materials for metallurgy and building materials, *8* forest resources (wood), *9* non-arboreal forest, *10* biological sea, *11* biological resources of rivers and lakes, and *12* soil. II. *Resource value*: *A* level of economic micro region, *B* level of Far East region, and *C* level of Asia-Pacific region. III. Boundary of the Amur River Basin

recreational resources. The areas of Northeast China, Khabarovsk and Primorsky Krais, and Amur Oblast have a diversity of natural resources and large reserves thereof (Fig. 1.1). At present, there are varying types of timber resource management related to forest exploitation, agriculture, water use, mining, construction, nature conservation, recreation, and others in the basin geosystem. However, in different countries and even within those countries, numerous homogeneous types of natural resource management have variable structures, stabilities, and efficiencies. There is a consensus of both national and regional interests that their shared objective is sustainable nature management throughout the basin.

In the Amur Basin, various activities in economic centers have been created. In the following, we describe characteristics of the natural resources, population, and economy in the Russian portion of the geosystem. The Amur region of Russia includes the Oblasts and Krais—subjects of the Russian Federation (RF)—territories that are mostly within the basin (Zabaikalye, Khabarovsk and Primorsky Krais, Amur Oblast, and the Jewish Autonomous Region). Integrated assessment of the natural resource potential (NRP) in basin territories covers not only the availability of certain types of resources, but also addresses proportions of separate NRP components within the framework of the international transboundary territory. That territory is an integrated geographic structure consisting of interacting border territories combined with particular natural resources, infrastructure objects, settlements, and economic activities within the boundaries of the greater geosystem (Baklanov and Ganzei 2008). The geographic makeup of natural resources in the Amur region is shown in Fig. 1.1. The available natural resources are shown, and their significance to the economy at local, regional, and international levels has been noted (Moshkov 2005). The greater part of the Amur Basin, as an international transboundary territory, is situated in two countries, Russia (Amur Oblast, Khabarovsk and Primorsky Krais, and Jewish Autonomous Region) and the PRC (Heilongjiang Province).

The distribution of reserves of certain types of natural resources across the basin is irregular. This is shown by data on the reserves, such as categories A, B and C (Fig. 1.1) for certain basic types (Tables 1.2 and 1.3). The arrangement of basic resource types is depicted in Fig. 1.1. For example, reserves of copper and nickel in Russian territory are less than those in the PRC. Conversely, proven reserves of manganese, titanium, and tin in the Russian part are not present in the Chinese part. There are substantial differences of NRP in the Russian and Chinese parts of the basin. This situation creates objective opportunities for complementarity, using NRP as the ability of separate territories to somewhat counterbalance the lack of certain natural resources in adjacent territories (Tkachenko 2009).

Land and water resources, forest, iron ore, tungsten, coal, tin, lead, and zinc are more evenly distributed among the basin countries. These types of natural resources are very promising with respect to foreign economic ties between the territories. Resources such as copper and manganese ore, titanium, and nickel are characterized by high complementarity. Therefore, these are the most promising for integrating into human activities across the basin territories, for both export and import. Emphasize the importance of the Russian and Chinese border within the Amur as having high potential for many types of natural resource development, based on efficient foreign economic relations.

Table 1.2 Percent shares of major types of natural resources in the Amur Basin, according to proven reserves. (Source: Tkachenko 2009)

Territories	Iron	Manganese	Tin	Tungsten	Lead	Zinc	Copper	Titanium	Coal	Nickel	Agr. lands	Forest
Primorsky Krai	0.5	0	56	35.1	75.6	35.4	0.1	0	8.2	0	5.9	16.8
Khabarovsk Krai	0	0	42	8.3	0.4	0.1	4.3	0	5.4	0	2.6	48.2
Amur Oblast	17.7	0	0	0	0	0	0	100	12	0	10	19.1
Jewish Autonomous Region	60	100	2	0	0	0	0	0	0.1	0	1.5	1.6
Heilongjiang	21.8	0	0	56.6	24	64.5	95.6	0	74.3	100	80	14.3
Russian part of Amur River Basin	78.2	100	100	43.4	76	35.5	4.4	100	25.7	0	20	85.4
Chinese part of Amur River Basin	21.8	0	0	56.6	24	64.5	95.6	0	74.3	100	80	14.3

Unit is %

Table 1.3 Natural resource potential of the Amur River regions

Regions	Natural resources												Value of resource			
	Coal	Oil and natural gas	Hydroenergy of rivers	Ferrous materials	Nonferrous metals	Chemical raw materials	Nonmetallic materials	Forest resources (timber)	Nonwoody resources of forest	Marine bioresources	Bioresources of rivers (lakes)	Land resources	Total	Including intraregional (%)	Far-Eastern (%)	Asian-Pacific Region (%)
1. Primorsky Krai	1	–	2	1	3	1	2	3	3	3	2	1	*22*	18	27	55
2. Khabarovsk Krai	1	–	2	2	3	1	1	3	2	3	3	1	*22*	18	27	55
3. Jewish Autonomous Region	1	–	1	3	3	1	2	1	1	–	3	2	*18*	28	22	50
4. Amur Oblast	1	–	3	1	3	1	1	3	2	–	3	2	*20*	20	20	60
5. Zabaikalye Territory	3	–	–	2	3	2	2	3	1	–	1	1	*18*	17	33	50
6. North–East China	2	2	2	2	3	1	1	2	2	–	3	2	*22*	9	64	27
Resource value total	*9*	*2*	*10*	*11*	*18*	*7*	*9*	*15*	*11*	*6*	*15*	*9*	*122*			
Including intraregional	4	–	1	2	–	5	3	1	2	–	1	3	22	18		
Far-Eastern	2	2	6	8	–	2	6	2	6	–	2	6	40		33	
Asian–Pacific Region	3	–	3	3	18	–	–	12	3	6	12	–	60			49

1.2 Sociodemographic Features

The Amur region ranks among the most populated in the Russian Far East. As of 1 January 2009, 5.5568 million people, or 3.9% of the Russian population, inhabited the region. A large proportion of these people (up to 90%) are concentrated in a belt between the Trans-Siberian Railway and the Amur region, and within the Trans-Siberian Railway zone of Primorsky Krai. Generally, this population and its density reflect a more developed economic territory, with a domestic regional market of greater capacity. However, this also represents a greater anthropogenic impact on the natural environment. There are substantial differences in these parameters, generating large transboundary gradients between the Russian and Chinese territories (Baklanov and Ganzei 2008). Subjects of the RF in the Amur region have varying demographic indices (Tables 1.4, 1.5, 1.6, and 1.7). However, compared with 1990, there are general regional tendencies, namely a reduction in population and in population growth seems redundant, plus an increase in the dependence ratio.

Life expectancy at birth of the population in the Amur region in 2008 reached 65.5 years for Primorsky Krai, 65.27 for Khabarovsk Krai, 63.53 for Amur Oblast, 62.66 for the Jewish Autonomous Region, and 63.82 for the Zabaikalye Territory. For the RF, this figure was 67.88. The most important factor revealing the attraction of people to the region is the migration gain coefficient per 10,000 people. Negative values of this factor are traditionally seen for all subjects in the Amur region (Table 1.4). However, in 2008 there were positive values in Khabarovsk Krai and the Jewish Autonomous Region. For most RF subjects in the region, high unemployment is characteristic (Table 1.5).

As a result, per capita income slightly exceeded the national average in most RF subjects of the Amur region (Table 1.6). However, incomes dropped below the national average in Primorsky Krai in 2000 and in Amur Oblast and the Jewish Autonomous Region in 1995. In the Zabaikalye Territory, incomes have not reached the national average since the 1990s.

1.3 Territorial-Branch Structure of Production

A combination of different types of economic activities and their balances within particular territories, districts, and subjects of the RF are considered territorial-sectoral structures in the Amur region. In these structures the primary industries examined include machine building, mining, forestry, food processing, and fishery. The study areas include the southern Far East, i.e., Khabarovsk and Primorsky Krais, Amur Oblast, the Jewish Autonomous Region, and the Zabaikalye Territory including the Chita region and Agin-Buryat Autonomous Area.

Table 1.4 Demographic indices of the Amur region. (Sources: Regions of Russia 2008; Russia in Figures 2011)

Subjects of RF	1990	1995	2000	2004	2006	2008	2010
Population size, thousand people, at the year end							
Russian Federation	148,274	148,292	146,304	143,474	142,221	141,904	142905.2
Primorsky Krai	2310	2242	2120	2036	2006	1988	1956.4
Khabarovsk Krai	1625	1544	1460	1420	1405	1402	1344.2
Amur Oblast	1054	986	923	887	875	864	829.2
Jewish Autonomous Region	219	207	193	189	186	185	176.6
Zabaikalye Territory	1318	1248	1179	1136	1122	1117	1106.6
Birth rate indices, number of persons who have been born per thousand mille							
Russian federation	13.4	9.3	8.7	10.4	10.4	12.1	12.5
Primorsky Krai	14.6	9.4	8.6	10.6	10.4	11.3	11.8
Khabarovsk Krai	15.1	9.4	8.5	11.3	11.0	12.2	12.9
Amur Oblast	16.2	10.6	10.2	12.4	11.8	12.9	13.8
Jewish Autonomous Region	17.8	11.1	9.7	12.0	12.1	13.9	13.6
Zabaikalye Territory	17.6	12.7	11.8	13.8	13.9	15.9	15.9
Rates of natural increase (per mille)							
Russian federation	2.2	−5.7	−6.6	−5.6	−4.8	−2.5	−1.7
Primorsky Krai	5.5	−3.7	−5.3	−5.1	−4.5	−3.2	−2.5
Khabarovsk Krai	5.9	−3.9	−5.6	−4.7	−3.9	−1.8	−1.7
Amur Oblast	7.6	−1.9	−4.4	−4.8	−3.7	−2.2	−1.5
Jewish Autonomous Region	8.2	−2.7	−4.8	−5.0	−3.9	−1.4	−1.9
Zabaikalye Territory	8.4	−0.6	−2.7	−3.3	−1.6	1.6	2.1
Rates of migration gain (per 10,000 persons)							
Russian federation	19	44	25	7	11	18	13
Primorsky Krai	1	−72	−44	−25	−22	−7	−36
Khabarovsk Krai	−27	−108	−38	−1	−10	5	−20
Amur Oblast	−86	−68	−91	−29	−37	−38	−44
Jewish Autonomous Region	−31	−86	−52	−3	−10	7	−35
Zabaikalye Territory	−98	−63	−91	−39	−38	−32	−44

1.3.1 Machine-Building Complex

In the territorial-branch structures of industry, machine building has an important structure-forming function as a result of extensive development of interbranch connections, which are based predominantly on cooperative principles. These connec-

Table 1.5 Unemployment rate in the Amur region (%). (Sources: Regions of Russia 2008; Russia in Figures 2011)

Subjects of RF	1995	2000	2002	2004	2008	2010
Russian Federation	9.4	10.6	7.9	7.8	6.3	7.5
Primorsky Krai	9.9	12.3	9.1	9.6	7.0	9.7
Khabarovsk Krai	11.4	12.2	7.0	6.6	8.7	9.1
Amur Oblast	13.2	13.7	10.8	11.2	5.1	6.9
Jewish Autonomous Region	16.2	15.0	9.1	8.3	10.1	9.4
Zabaikalye Territory	9.2	14.4	11.1	12.4	14.9	9.3

Table 1.6 Per capita income in the Amur region (monthly, in rubles; except 1995, thousands rubles). (Source: Regions of Russia 2008; Russia in Figures 2011)

Subjects of RF	1995	2000	2002	2004	2008	2010
Russian Federation	516	2281	3947	6410	14,939	18,552.6
Far East	649.3	2497.6	4391.4	7046.9	15,622.0	20,809.1
Primorsky Krai	540	1800	3122	5405	12,808	17,263.8
Khabarovsk Krai	536	2500	4689	7597	15,705	22,545.0
Amur Oblast	513	1825	2875	4695	11,936	14,057.8
Jewish Autonomous Region	416	1489	3081	4975	10,877	15,180.3
Zabaikalye Territory	436	1406	2993	4800	10,972	14,112.1

Table 1.7 Machine-building in Far Eastern Federal District (FEFD) subjects in 2009 (by type of economic activity). (Sources: Primorye in the Far Eastern Federal District 2009. Bulletin. Vladivostok: Primorskstat 2010)

Subjects of FEFD	Production of machinery and equipment		Production of electrical, electronic and optical equipment	
	$\times 10^6$ rubles	in % of 2008	$\times 10^6$ rubles	in % of 2008
Khabarovsk Krai	3079.4	71.7	1465.2	65.9
Primorsky Krai	11772.8	89.1	2830.5	1.6
Amur Oblast	386.1	63.0	164.7	63.5
Jewish Autonomous Region	46.0	57.2	285.6	81.9

tions serve as the most important condition for functioning of all elements of the regional economic system, because they meet demand in regional markets for goods for both manufacturers and consumers. Under conditions of the administratively planned economy, the complex geopolitical environment in the Asia-Pacific Region (APR) and the need to perform a state defense function proved to be the leading factors of formation and development of the machine-building complex. Because regional development was based on use of the richest NRP, the primary focus of machine building was the provision of necessary machinery and equipment to the extractive industries. The machine-building complex is subdivided into the following branches: general engineering, precision engineering, electrical engineering, transport machine building, agricultural engineering, chemical machine building, and others. At present, machine building in the region is manifested by the production of machinery and equipment, including electrical, electronic, and optical equipment (Table 1.7).

In the machine-building structure of the Amur region, the types of economic activity meet the needs of machinery and equipment repair for sea fishery and transport vessels, machine and tool production, navigation instruments, various metallic structures, major appliances, and others. Defense enterprises constitute a large part of this. Essential factors of competitiveness for engineering products are high quality and technological novelty, especially in the newest fields. Within the study area, only a small portion of products is directly consumed, which can be explained by a high level of production specialization and sales networks with respect to both finished products and component parts. There is strong import dependence with regard to consumer goods. The import of products from APR countries has a decisive influence on opportunities for marketing of products from the machine builders in the Amur region. For example, in the machine-building complex of Khabarovsk Krai, branches that produce market goods are heavy engineering construction, shipbuilding, aircraft engineering in Komsomolsk-on-Amur, and instrument engineering in Khabarovsk. In Amur Oblast, the machine-building industry is composed of ship repair in Blagoveshchensk, manufacture of transportation facilities at Kranspetsburmash works in the town of Shimanovsk, production of skidders and log loaders mounted on artillery offroad vehicles, and assembly of garbage trucks and vacuum cleaners for public services. Bureya-Kran, a JSC (joint-stock company) in the Novobureisky produces plants for processing of mined rock from gold-bearing placers. The Amurselmash works in Belogorsk manufactures a new modification of solid fuel boilers and others. The machine building industry in the Jewish Autonomous Region includes the JSC “Birobidzhan power transformers plant” and an automotive equipment maintenance plant. The Chita region produces machine tools. In Primorsky Krai, there is aircraft engineering in Arsenyev, instrument making in Vladivostok and Partizansk, and shipbuilding in Vladivostok, Nakhodka, Bolshoy Kamen, Slavyanka, and Preobrazheniye.

An essential part of the regional machine-building complex is formed by defense enterprises in Komsomolsk-on-Amur, Khabarovsk, Vladivostok, Arsenyev, and Bolshoy Kamen, the products of which are characterized by high quality and a unique character. Therefore, these have a steady demand in the world military market. A positive effect of the introduction to the Amur region of advanced crop cultivation technologies has been additional market opportunities for agricultural engineering products. Support from regional authorities could make this branch of machine building very promising. With agricultural engineering branches, some conversion enterprises, including JSC Askold in Arsenyev, are successfully in competition.

Transport machine building in the region is represented by repair facilities, e.g., locomotive repair shops, ship-repair yards, and motorcar repair enterprises in Primorsky, Khabarovsk Krais, and Amur Oblast, where goods are manufactured for the market as a means of production. Companies in the PRC, Japan, South Korea, and Singapore are powerful competitors of the Far Eastern machine-building complex in the shipbuilding and ship-repair services markets. However, a persistent demand for products, the protectionist policy of the state, and a reduction in repair terms can ensure that earlier, more stable states of Russian enterprises in the shipbuilding and ship repair markets can be maintained in the APR. In a time of economic reform, the share of the machine-building complex of regional industry has almost halved. In the mid 1990s, there was a particularly substantial reduction in the manufacture of engineering products in Primorsky Krai. In Khabarovsk Krai, the pre-reform position of the industry was restored only in 1998, largely through defense orders. As a specific constituent of structural variations in machine building, we consider the defense complex conversion that has occurred in regional enterprises since the 1990s. During conversion, many productive facilities of this complex were reoriented toward civilian industry. Therefore, inter-industry relations of machine builders have changed greatly. In the machine-building centers where defense enterprises were located, integral systems of life support based on those enterprises developed in population centers. Normal operation of these township-forming enterprises has ensured a trouble-free, socioeconomic environment for local residents. In the defense enterprises of major polyfunctional cities, the most skilled personnel were concentrated, and advanced technologies were introduced that resulted in high-quality output products. The planned economy ensured steady sales of products, locally and abroad. During the economic reform, demand for products from these machine builders significantly declined. The new national defense doctrine has resulted in military contraction. This conversion caused a substantial reduction in government orders for military products.

The entry of Amur region defense enterprises under the control of governmental authorities into the world arms market can strengthen their financial positions, assist equipment modernization, and facilitate the manufacture of more competitive products, including those in civilian industries. In the 1990s, the situation of civilian industries in the machine-building complex also became difficult. The demand for casting, metalworking, woodworking machines, sanitary fixtures, and other products has considerably subsided (Table 1.8). This is explained by a decline in production and financial hardship of industrial consumers of these products, namely, the ship-repair, forestry, woodworking, and building industries. There has been slight growth of production volumes in these industries only since 2001.

Regions turning out consumer products are Khabarovsk, Primorsky Krai, and Jewish Autonomous Region in the Far East, and the former Chita region in the Transbaikalia. For example, television sets are manufactured at the Rodina plant of Ussuriysk in Primorsky Krai, at a plant producing household appliances in Komsomolsk-on-Amur in Khabarovsk Krai and the Jewish Autonomous Region. Washing machines are manufactured in Ussuriysk and Komsomolsk-on-Amur, as are refrigerators and freezers in Primorsky and Khabarovsk Krais. Prospects for development of civilian production in the machine-building complex are closely related to the participation of Krai enterprises in the international geographic division of labor within the APR. Enterprises of the Amur region machine-building complex maintain considerable scientific and production potential, which permits them to meet numerous demands of economic sectors and the regional population for means of production and consumer goods. Regional defense enterprises turn out high-quality products that are in great demand in the world arms market.

Table 1.8 Output of basic types of civilian products in machine building. (Source: Regions of Russia 2008)

Products	1990	1995	2000	2002	2004	2006
Production of metal-cutting machines, pcs						
Far East	839	530	82	37	–	–
Share of Amur region in the FE production, %	100	100	100	100	–	–
Share of Amur region of FE in the Russia production, %	1.1	2.9	0.9	0.6	–	–
Chita Region	795	125	62	19	20	–
Share of Chita Region in the Russia production, %	1.1	0.7	0.7	0.3	0.4	–
Production of refrigerators and home freezers, × 10^3 pcs						
Far East	151.5	0.3	–	21.8	128.7	152.0
Share of Amur region in the FE production, %	100	100	100	100	100	100
Share of Amur region of FE in the Russia production, %	0.6	0.01	–	0.7	3.6	3.8
Production of washing machines, × 10^3 pcs						
Far East	191.8	3.3	7.1	115.9	299.4	201.5
Share of Amur region in the FE production, %	100	100	100	100	100	100
Share of Amur region of FE in the Russia production, %	3.5	0.2	0.7	8.5	20.6	9.9
Production of TV sets, × 10^3 pcs						
Far East	–	8.1	18.3	215.7	408.2	98.5
Share of Amur region in the FE production, %	–	100	100	100	100	100
Share of Amur region of FE in the Russia production, %	–	0.8	1.6	10.9	8.7	2.1

Based on the manufacturing-sales ties of machine builders, interrelated, intersectoral territorial production systems of industry are established, which favorably impacts the efficiency of economic activity in the region. Social and economic efficiencies of enterprises entering similar territorial-sectoral systems improve with reductions in operating cycle time and transportation costs. In addition, development of production facilities favorably affects society. Unemployment decreases and, through enterprise and personal income taxes, it is possible to increase the revenue side of local budgets and finance social programs. However, a similar integration potential for regional machine builders is insufficiently realized at present.

1.3.2 Forest Industry Complex

Forestry enterprises of the Amur region are timber cutting, woodworking, and cellulose and paper production. The regions of Primorsky, Khabarovsk Krais, Amur

Oblast, and Chita specialize in the timber and woodworking industry. In the mid 1990s, there were declines of more than 75 % in harvest cutting and 50 % in sawmilling within those regions. More than 90 % of wood-based panels and industrial chips were produced in Primorsky and Khabarovsk Krais, plus 100 % of cellulose, paper, and cardboard in Khabarovsk Krai and 100 % of plywood in Primorsky Krai. The industry performs a most important social and economic function, through providing employment and ensuring incomes for local budgets in underdeveloped taiga areas. In addition, timber is one of the stable Russian goods exported to foreign markets. A large part of the country's and Far Eastern region's forest-industry complex products are from the Amur region. For example, the timber, woodworking, pulp, and papermaking industries of the Far East represented 5.2 % of total manufacturing output in the Far Eastern Federal District (FEFD). In the Amur region, leading timber positions during the mid 2000s, such as the woodworking and pulp and papermaking industries, were taken by the Jewish Autonomous Region (20.4 % of total industrial production), Khabarovsk Krai (13.3 %), and Primorsky Krai (8.5 %).

The dominant forest industry is timber. It procures high-quality raw wood, the large part of which is from outside the Amur region and abroad. Possibilities of the local woodworking base are traditionally related to timber procurement. For example, in 1990, about 47 % of converted wood was delivered to Far East woodworking enterprises; this declined to 19 % in 1995. In the reform period, there was a decline in output of nearly all types of products from the forest-industry complex (Table 1.9). The main reasons for this are related to existing traditional approaches to timber harvesting and declining productivity of forests in the region. Opportunities for production modernization are to a large extent limited by a decrease in profitability of production in all branches of the timber complex.

Khabarovsk Krai is the largest manufacturer of forest products in the region. Its share, 5.2 % of all rough timber produced in Russia (or 5.9 million m^3 of dense timber), fell in 2010. In the late 1990s, the output of wood veneer and chipboards in the Far East ceased, and the use of production capacities for the manufacture of sawn wood products and parquet declined drastically. The manufacture of wood veneer resumed in 2004, but on a limited scale (500 m^3) in Amur Oblast. The timber and woodworking industries are basic within the structure of industrial clusters in the taiga regions. The reduction in volumes of timber harvesting and hauling in the forest industry centers is caused primarily by the high costs of manufacturing forest products. Output volumes of commercial timber and sawn wood products have also greatly dropped. The primary costs related to product output in the industry are fuel and labor. A long production period prevents accumulation of sufficient circulating assets for organization of the normal operating process.

A relatively consistent demand for commercial timber in APR countries led to more moderate production slumps in industrial centers of timber procurement than in woodworking centers. Demand of traditional and new consumers in foreign markets had an overall favorable impact on specialized industries in the region. Product exports have consistently increased in the Far East, which has allowed many enterprises in the industry to avoid bankruptcy or even increase timber-harvesting volumes for export. For example, exports of timber, cellulose, and paper goods from

Table 1.9 Output of basic product types of the forest industry complex. (Source: Regions of Russia 2008)

Products	1990	1995	2000	2002	2004	2007
Production of commercial timber, × 10^3 m^3 of dense timber						
Far East	23,456	7370.3	8450.5	10,580	12,191	14,298
Share of Amur region in the Far East, %	77.6	79.7	87.2	89.2	92.8	93.9
Share of Amur region of the Far East in Russia, %	7.1	6.3	9.1	11.2	12.3	12.7
Zabaikalye Territory, including Chita Region Agin-Buryat Autonomous area	2723.8 61.3	525.2 7.4	342.1 5.2	309.4 3.1	592.8 7.1	1045.0 9.2
Share of Zabaikalye Territory in Russia, %	10.9	0.6	0.4	0.4	0.6	0.9
Production of sawn wood products, × 10^3 m^3						
Far East	5414.1	972.7	673.3	830.2	1146.1	1341.2
Share of Amur region in the Far East, %	70.7	61.6	65.4	70.2	75.5	79.1
Share of Amur region of the Far East in Russia, %	5.1	2.3	2.2	3.1	4.1	4.4
Zabaikalye Territory, including Chita Region Agin-Buryat Autonomous area	1064.6 48.6	254.5 6.6	78.0 2.1	88.9 1.3	142.4 2.8	252.8 7.0
Share of Zabaikalye Territory in Russia, %	1.5	0.9	0.4	0.5	1.1	1.1
Production of wood veneer, × 10^3 m^3						
Far East	25.3	1.0	–	–	0.5	0.001
Share of Amur region in the Far East, %	100	100	–	–	100	100
Share of Amur region in Russia, %	1.6	0.1	–	–	0.02	0.0
Production of cellulose, × 10^3 t						
Far East	539.9	60.0	11.3	4.6	–	–
Share of Amur region in the Far East, %	48.9	45.7	–	–	–	–
Share of Amur region of the Far East in Russia, %	3.5	0.6	–	–	–	–
Production of paper, × 10^3 t						
Far East	215.5	14.2	9.5	4.6	–	–
Share of Amur region in the Far East, %	5.4	1.1	–	–	–	–
Share of Amur region of the Far East in Russia, %	0.2	0.001	–	–	–	–
Production of cardboard, × 10^3 t						
Far East	240.6	13.1	32.8	30.8	21.2	24.0
Share of Amur region in the Far East, %	64.7	38.2	70.7	88.3	100	100
Share of Amur region of the Far East in Russia, %	5.1	0.4	1.2	1.1	0.7	0.6

the Far East reached 394.0 million $ in 2006. Among these exports, rough timber is dominant and constitutes as much as 99 % of exported products in the industry, which is explained by peculiarities of foreign demand. The territorial-branch structure of the forest-industry centers also underwent changes during the economic reform period. The processed volume of harvested wood significantly declined. Basic production assets such as woodworking equipment age and are eventually scrapped, and volumes of capital construction rapidly decline. The situation in industries with renewal of fixed production assets is more satisfactory than in other sectors of Krai industries.

Forestry and woodworking enterprises were able to maintain high rates of equipment upgrade, using income from exported products. Under these conditions, changes in the territorial-sectoral structure of forest industry centers were mainly the establishment of new enterprises and closures or re-specialization of unprofitable enterprises. The most complex situation was in woodworking enterprises producing sawn wood products, wood veneer, chipboards, cellulose, paper, and cardboard. This situation slightly improved only after default in 1998, when an added incentive for production increase in export industries appeared. During 2000–2006, the utilization efficiency of production capacities for sawn wood products and industrial chips significantly increased.

Enterprises operating in the markets of woodworking industry products are primarily oriented toward demand and good transport accessibility of consumers and high-income populations. In Primorsky Krai, these mainly include furniture enterprises in Vladivostok, Artem, Ussuriysk, Dalnerechensk, and Lesozavodsk. During the shift to a market economy, the most serious problem faced by enterprises in the Amur region forest-industry complex was production. The high cost of products from Primorsky Krai, owing to considerable expenses for energy and transportation services, made competitiveness of enterprises there less than that of forest products from northern European Russia and the Urals. Major domestic markets for products of Primorsky timber complex enterprises are within the Krai itself. Lacking customers in Russia, these enterprises search for foreign markets for their products (including sawn wood) and commercial timber.

APR countries are traditional markets for Amur region forest and woodworking industry products, which are primarily commercial timber and sawn wood. However, regional domestic enterprises in the furniture goods market face difficulties of production, because of large quantities of foreign-made furniture. These products are often made of Russian timber, have an appealing appearance, and are extensively brandished. In parallel with domestic enterprises, joint ventures and foreign enterprises have been recently established in various market segments of timber industry goods. Considering the number of joint ventures, number employed, and volume of output products, the forest and woodworking industry ranks next to the food industry (primarily fishing).

Apart from products made from woody resources of the forest (commercial timber and sawn wood), there are joint and foreign enterprise export goods made of non-wood resources (e.g., ginseng and unossified sika deer antlers). Income from sales of these goods frequently exceeds by many times that from woodworking products, and from sawn wood in particular. However, this is much less than income from sales of traditional goods, such as commercial timber. The most critical problem of the Amur region forest complex is a severing of industrial-engineering relations between procurement and processing enterprises. Because of privatization, timber cutters acquired the raw-material bases of industry and woodworking enterprises acquired the processing facilities. At present, domestic woodworking enterprises have no circulating assets. These enterprises have traditionally taken credit from banks for the full wood-harvest season but, because of high interest rates of commercial banks and problems with product sales, they could not pay for acquiring raw materials. The potential for interaction between extractive and processing enterprises in the industry remains unrealized.

Timber procurement enterprises were forced to deliver round logs products to foreign markets. However, uncontrolled mass export resulted in the flooding of APR markets. Price drops for raw timber caused substantial financial losses among its exporters. Forest harvesting enterprises attempted to expand into new, more profitable markets of finished products. For example, JSC Terneiles at Plastun in Primorsky Krai established a joint sawmill venture with Japanese firms. The woodworking enterprises solve raw-material provision problems by acquiring cheaper timber from other regions of the country, which proves advantageous despite higher transportation costs. In addition, the integrated woodworking plants acquire their own raw-material bases. For example, the Primorsky integrated Dalnerechensk woodworking plant has its own harvesting area. The challenge for domestic and joint enterprises of the timber and woodworking industry in the district and Krai is to maintain the current foreign market situation. In addition, it is necessary to strengthen their positions in domestic furniture markets, in which foreign competitors are active.

1.3.3 Fishing Industry Complex

The fishing industry in Amur is characterized by strong development (Table 1.10).

The fish industry is one of the basic branches of the economy in most Far East regions. In the Amursky region, this industry includes enterprises of various industrial sectors, namely suppliers of raw stock and materials, as well as consumption of products and the natural raw-material base. In the mid 1990s, more than 65 % of fish and seafood in Russia, and 50 % of fish product output, were from the Far East. At present, the major operational area of the fishing fleet is within the 200-mile Russian fishing zone, where nearly all fish and seafood are caught.

The major facilities for fish and seafood processing are in Primorsky and Khabarovsk Krais, with the largest fishing enterprises in Primorsky. In 2010, their share of Russian fish output and processed and preserved fish products was 16.7 % (597,000 t, plus 89.8 million standard cans of natural canned fish). Prior to the economic reforms, the fishing industry of Primorsky Krai included 12 large industrial enterprises, five scientific production-and-design organizations, and eight fishing

Table 1.10 Harvesting of fish and other seafood in the Amur region (×10³ t). (Sources: Industry of Russia 2002; Russian Statistical Yearbook 2008)

	1990	1995	2000	2002	2004	2006	2007
Far East	4627.9	2810.1	2278.5	1761.4	1741.4	2000.2	2231.7
Share of Amur region in total FE catch, %	47.6	54.8	48.5	40.7	39.6	39.1	37.9
Share of Amur region of FE in total Russian catch, %	27.9	39.1	29.3	22.0	23.2	23.9	24.8
Zabaikalye Territory including Chita Region	7.3	4.2	2.9	0.03	2.3	2.4	0.01
Share of Zabaikalye Territory in total Russian, %	0.09	0.1	0.08	0.001	0.08	0.07	0.0003

Table 1.11 Products of the Far East fishing industry. (Sources: Leonov et al. 2007; Industry of Russia 2010)

	1991	1995	2000	2002	2003	2005	2007	2009
Marketable fish products (fish and sea food), thou. t	4062.2	2816.2	2292.9	1761.4	1991.7	1972.1	2231.7	2247.3
Canned fish, $\times 10^6$ standard cans	1000.7	274.2	114.2	156.1	229.4	215.9	196.2	213.7

kolkhozes. At present in Primorsky, more than 167 fishing industry enterprises operate, 23.3 % of which are of large-scale and medium-size, and 76.7 % are small. Primorsky Krai is a leading fishing region, with more than 40 % of annual volume of fishery sector output in the Far East fishing basin. The economic reforms significantly altered the industry composition and structure. New fishing enterprises were established (joint-stock and private companies, plus joint ventures, including those with foreign funds). In such cases, there should be fundamental reconstruction of onshore fish-processing plants to augment fish and seafood processing. However, fishing companies encountered serious industrial and financial problems. A stable domestic demand for fish products contributed to the successful operation of enterprises. Recent activities in the Far East fishing industry are described in Table 1.11.

Major catch volumes have resulted from active deep sea fishing by oceanic fishing bases. Major target species were Alaska pollock, salmon, and crabs, whose catch quotas were met in full. Within the national fishing zone, the major fishing area was the Sea of Okhotsk (70 % of fish and seafood originated there in 1996). Commercial inshore fisheries were almost non-existent. Such a situation eliminated the possibility of increasing and maintaining volumes of fish caught and, therefore, fish products. The main reason for the decline in operational efficiency of fishing industry enterprises in the Far East was depletion of the raw-material base of traditional species in deep-sea fisheries of Alaska pollock and herring, and the limited raw-material processing capacity. In addition, servicing of fishing vessels (supplies of fuel, water, food, and others) was unsatisfactory. There were difficulties in transferring catches to fish-processing vessels or onshore plants. An aging fishing fleet is evident. As early as 1992, equipment deterioration of fishing, fish processing, and transport vessels reached 70, 60, and 50 %, respectively.

Independent accounting enterprises indicated that from the mid 1990s, upgrade rates of old-fashioned basic production assets in the fishing industry lagged behind those of outdated equipment retirement. Such a situation of fixed-asset upgrade was created in spite of major investment channeled into those assets. A difficult situation persists for ship-repair facilities traditionally oriented toward fishing vessels. Such facilities in the region have a deficit of orders. Reasons are high transportation tariffs and a lack of metal, spare parts, timber, paint, lacquer material, and other supplies. In addition, repair costs are affected by high energy prices in the region. The export of fish products has become the major supplement to the financial resources of companies, including funds for modernization of fishing and fish-processing equipment in the industry. Therefore, tax incentives and customs privileges are necessary for purchases by fishing enterprises of foreign-made spare parts, components, and equipment. In addition, it is important to stimulate interest within the companies for products of Russian manufacture, e.g., for fishing vessels and navigation equipment produced in the Amur region. High-quality fish and seafood guarantees consistent demand for these products in APR countries. This includes demand for products of both oceanic and inshore fisheries, e.g., caviar of sea urchins, sea cucumber, scallops, crabs, and shrimp. Laminaria demand is especially high in countries of the Japan Sea region. The most important problem of the Amur region fishing industry complex is reorientation from expensive oceanic fishing to inshore fisheries, which are cheaper and fully geared to mass domestic consumption. In this way, fishing enterprises that faced problems related to a lack of special fishing gear and small harvesting vessels can embody an environmentally friendly fishery mode within offshore aquatic areas.

The region already has successful manufacturing practices for small fishing craft, including those within defense enterprises in the town of Bolshoy Kamen. For organizing effective inshore catching of fish and seafood, several problems should be resolved. First, it is necessary to define the legal status of small fishing and fish-breeding firms, and to protect their interests in conflicts with major fishery companies over fishing areas and product markets. Given the above, it is necessary to harmonize the interests of federal and local authorities by fostering regional programs of fishery sector development. Enactment of federal fishery laws would allow legislative organization of interrelations between federal authorities and regions. This should ultimately resolve the problem of sustainable use of the NRP of industry in the Far East.

1.3.4 Nonferrous Metallurgy

Nonferrous metallurgy in Amur is represented by mining related to the extraction and primary processing of mineral raw materials. These include nonferrous metal ores and concentrates of nonferrous metals, and manufacturing activity such as ferrous and nonferrous metallurgy. The latter was developed in Amur Oblast, where its share reached 23.9 %. The figures for Khabarovsk Krai were 12.7 %, Zabaikalye in the Chita region 35.85 %, and the Agin-Buryat Autonomous Area 16.8 %. Mining within the metallurgical complex of the Far East and Chita region includes extraction of nonferrous metal ores and production of concentrates. That extraction of precious metals, tin, lead, zinc, tungsten, metallic bismuth, and others is one of the specialized branches of the Amur region. Most natural resources extracted by enterprises in the mining complex of Amur are of national significance. For example, considerable quantities of tin, tungsten, gold, silver, platinum, lead, and zinc are mined only in this region. Major problems of these industries are related to rises in prices of fuel, electricity, material, and transport tariffs, plus high tax rates. Major regional gold-mining areas are Zabaikalye Territory, Amur Oblast, and Khabarovsk Krai. Production of tin, tungsten, and lead-zinc ore concentrates is found in Primorsky and Khabarovsk Krais, as well as in Zabaikalye Territory of the Chita region.

Industry development requires continuous replacement of reserves, additional in-mine exploration of new fields, complex processing of raw materials, and waste treatment. For technical re-equipping of industry enterprises, emerging investments are required. High tariffs for electric energy and transportation of concentrates to metallurgical treatment centers are currently the major problems for efficient development of the industry in the region. The major problem for developing mining enterprises in the industry is product sales of different ores and concentrates. In the Far East, there is a lack of facilities for metallurgical treatment of concentrates and for production of nonferrous metals and various alloys on their basis. The absence of final stages of raw material processing is explained by properties of the lead-zinc concentrates, i.e., high contents of valuable elements and, accordingly, their high transportability. The stages of extraction, enrichment, and metallurgical treatment are territorially dissociated. For example, a small lead smeltery (JSC Dalpolimetal at Rudnaya Pristan in Primorsky Krai) is unable to process the full amount of concentrate produced. There is an analogous situation in the lead and tungsten extraction industries. The metallurgical treatment of tin concentrates is unrelated to sources of raw materials, but is located along the route of concentrate transport to the city of Novosibirsk or within areas of finished product consumption.

In Primorsky Krai, there are conditions for establishment of its own metallurgical base for the making of finished metal, i.e., raw materials and product consumers represented by machine builders. In 1998, a project was developed for an integrated hydrometallurgical works in the Svetlogorye settlement for processing of tungsten concentrate into finished metal and production of other valuable metals. This project was based on the existing Lermontov mining company, the Primorsky branch of LLC Russky Volfram (Russian tungsten) in Primorsky Krai. In the integrated works, the use of technology developed by Novosibirsk researchers is assumed, which allows 40 % efficiency improvement in the extraction of commercial components from tungsten concentrates produced in the krai. The accompanying element during extraction and concentration of tungsten trioxide in the Primorsky mining and processing complex at Vostok-2 in Primorsky Krai is copper concentrate, which contains arsenic. Participation of both domestic and foreign companies in the organization of copper concentrate processing is acceptable. Earnings derived from certain enterprise product exports are another source of financial assets, for realization of nonferrous metallurgy reconstruction and development programs.

Despite high quality even relative to worldwide standards, products of the tungsten industry enterprises do not have Russian markets; therefore, these enterprises are forced to orient themselves to foreign markets. Another unique enterprise in the Far East is the open JSC Yaroslavsky Mining and Processing Works (OJSC YMPW) at Yaroslavsky in Primorsky Krai, where about 80 % of the Russian volume of fluorspar concentrate is produced. This concentrate was processed in iron and steel works outside the Far East. The uniqueness of raw materials and concentrate produced, together with regulation by government tariffs on electricity and transport operations, made products of the OJSC YMPW competitive in the Russian market. As early as 1994, the enterprise had orders for all its products. However, since the mid 1990s, output volume has declined. In 1992, the works produced 293,500 t of fluorspar concentrate. In 1996, this figure decreased to only 32,300 t and the work was abandoned in 1997. Being in a difficult financial position, consumers of YMPW products were forced to execute settlements in kind, such as for aluminum, refrigerators, and others.

The major cause of decline in demand for YMPW products was competition from foreign manufacturers of fluorspar, in the absence of a protectionist policy of the Russian government. Significant customs privileges given to importers of fluorspar in Russia contributed to displacement of YMPW products from this market segment and suspension of production. Enterprise operation resumed only after joint actions of the Krai administration and government toward reduction of tariffs on transport of YMPW products and electricity, plus exemption from Krai tax payments and increased customs charges for import of concentrate from Mongolia and other measures. Further development of the enterprise is related to essential capital expenses for reconstruction of production through federal credits and tax privileges.

The most important determinants of the peculiarities and directions for development of mining complex enterprises in the Amur region are: (1) small demand of traditional and new consumers; (2) a rise in prices for electricity, raw stocks, and materials; (3) aging equipment and sluggish renewal of fixed production assets; and (4) competition for domestic and foreign consumers. Prospects for development of the Amur region mining complex are related to its structural transformation, i.e., organization of its own metallurgical base capable of processing nonferrous metal ores and concentrates into end products. This will not only improve production efficiency via integrated processing of raw materials and recovery of accompanying rare and precious metals, but will also allow entry to new segments of the world market (e.g., finished metals). For example, there are presently technological developments for organization of processing of all concentrates produced in Primorsky Krai, based on the lead smelter at JSC Dalpolimetal at Rudnaya Pristan in Primorsky Krai. In particular, these developments include the processing of lead-zinc concentrate with zinc production, lead and accompanying metals, tin ores, and extraction of tin and accompanying metals. In addition, based on use of waste tin-ore extraction and processing, there could be production of sulfuric acid, the demand

Table 1.12 Output of major types of ferrous metallurgy products in the Amur region. (Sources: Regions of Russia 2008)

	1990	1995	2000	2002	2004	2006
Output of rolled ferrous metal products, ×10^3 t						
Far East	1211	128	389	399	614	755
Share of Amur region in output of rolled ferrous metal products in Far East, %	100	100	100	100	100	100
Share of Amur region of FE in output of rolled ferrous metal products in the country, %	1.9	0.3	0.8	0.8	1.1	1.3
Chita Region	256	84.4	4.6	0.3	–	–
Share of Chita region in output of rolled ferrous metal products in the country, %	0.4	0.2	0.01	0.001	–	–
Steelmaking, ×10^3 t						
Far East	1408	146	400	417	638	810
Share of Amur region in steelmaking in FE, %	99.1	96.4	99.4	99.5	99.7	99.9
Share of Amur region of FE in steelmaking in the country, %	1.6	0.3	0.7	0.7	0.9	1.1
Chita region	263	95.3	14.3	0.1	0.1	0.03
Share of Chita region in steelmaking in the country, %	0.3	0.2	0.02	0.0002	0.0002	0.0

for which is high within the JSC Bor. The efficiency of such production increases with inter-industry cooperation of mining complex enterprises and reduction of environmental pollution from production waste.

1.3.5 Ferrous Metallurgy

Ferrous metallurgy in the region has traditionally been maintained. In 2004, the industry share of industrial product output in the majority of regions did not exceed 1.0 %. The exception was Khabarovsk Krai (7.3 % of the industrial product). In this krai, there is the only semi-integrated works in the Far East—OJSC Amurstal in Komsomolsk-on-Amur. Steel in the Far East portion of the Amur region is manufactured in Khabarovsk and Primorsky Krais, as well as in Amur Oblast. The major share is found in Khabarovsk Krai, and finished steel is made only there. During the socioeconomic reforms of the 1990s, there was considerable reduction in output volumes of the major types of industry products, in connection with a general reduction in demand for investment goods (Table 1.12).

The manufacture of rolled ferrous metal products in Amur fell more than 1.5 times between 1990 and 2006, while the nationwide decline reached only 9.7 %. In the Chita region, this manufacture (the Petrov-Zabaikalsky works) halted in 2003. The major problems of ferrous metallurgy in the region are high production costs owing to high transport and energy tariffs, plus low competitive ability of products in Russia and APR countries.

1.3.6 Fuel and Energy Complex

Fuel and energy within the regional industrial complex includes two sectors, extraction of fuel (coal) and generation of electrical and heat energy. The fuel and energy complex has a significant influence on the economic structure of all administrative-territorial units in the region. The current situation is characterized by a general decline in volumes of production within all branches of the economy, as well as by change of price parity in favor of fuel and energy complex products. For example, the share of fuel and energy complex branches in the gross industrial product of the Far East reached 30.1 % in 2004, 19.6 % accruing to the electrical energy industry and 10.5 % to the fuel industry. Only the nonferrous-metals industry had a comparable volume of industrial products (29.7 %) in the Far East.

All subjects in the Amur region have considerable reserves of fuel and power resources, as follows: (1) nearly all regions have adequate coal reserves; (2) it is possible to use the hydraulic power potential in Chita, Amur Oblast, Primorsky and Khabarovsk Krais; and (3) prospective reserves of oil and natural gas are concentrated in the oil-and-gas provinces of Amur-Bureya and Okhotsk. The structure of energy generation in the Amur region was created with consideration of the following energy policy: (1) efficiency of energy generation with concentration of energy resource production; and (2) large-scale power engineering facilities, constructed with reliance on wide inter-territorial cooperation for the supply of energy resources and energy sales. The switch to market principles of the economy demanded changes in structural development of the regional fuel and energy complex. For example, increase in prices of energy products and in tariffs on energy and fuel transport from beyond the Far East region forced regional authorities to develop their own socio-economic policies, based on the concept of energy independence.

The production of fuel resources, a primary component of the fuel and energy complex, was subjected to substantial organizational restructuring. The object of such reforms was the strengthening of the market position for efficient self-development of coal mining. The leading coal mining associations in the region have received subsidies in accord with an industry restructuring government program. This program recommended an increase in volumes of coal extraction, with closure of unprofitable mines and predominant development of open-cut mining. In the majority of RF subjects in the Amur region, coal remains the principal fuel resource (Table 1.13). For example, the share of coal in the fuel balance reached 68 % in Primorsky Krai, 65 % in Khabarovsk Krai, and 58 % in Amur Oblast. However, coal production has greatly decreased relative to 1990.

The largest coal mining centers in the Far East part of the Amur region are in Primorsky Krai. In 2010, coal-mining enterprises there produced 10.4 million t of coal. Most production is by surface coalmines. In the Far East part of the region, these are the Luchegorsky and Pavlovsky open cuts in Primorsky Krai. Among the coal-mining centers, the Luchegorsk, Novoshakhtinsk, and Lipovtsy settlements are the most significant. In the Transbaikalia, the two largest surface coalmines in the Chita region (Kharanorsky and Vostochny) operate successfully. In 2010, the volume of

Table 1.13 Coal production in the Amur region (× 10³ t). (Sources: Regions of Russia 2008; Russia in Figures 2011)

	1990	1995	2000	2002	2004	2006	2007	2010
Far East	49,756	33,850	28,353	30,061	31,894	32,054	32,188	31.6[a]
Share of Amur region in coal production in FE, %	49.6	50.2	51.3	53.3	51.5	50.1	40.8	42.4
Share of Amur region of FE in coal production in the country, %	6.2	6.5	5.6	6.3	5.8	5.2	4.2	4.2
Zabaikalye Territory	9969	12,462	13,225	10,495	9207	9223	13,518	16.2[a]
Share of Zabaikalye Territory in coal production in the country, %	2.5	4.7	5.1	4.1	3.3	2.9	4.3	5.1

[a] in $\times 10^6$ t

coal production in the Zabaikalye Territory reached 16.2 million t. Practically all coal-mining open pits in the region belong to the Siberian Coal Energy Company (SCEC).

The dynamics of coal-mining volumes have a considerable impact on the generation of electric and heat energy at thermal electric power stations in the Amur region. For example, a deficit of fuel in the Dalenergo Association is supplemented by supplies from East Siberia, Zabaikalye, and Yakutia. A deficit of coal for industrial consumers and the population persists in the fuel balance of Primorsky Krai. Decline in coal production is largely caused by a lack of necessary centralized capital investments for development of this key krai economic branch. We note efforts of local authorities to support the coal-mining enterprises, in particular, the establishment of small surface coalmines.

The supply of power-generating coal will continue in the near future in Krasnoyarsk Krai, Kemerovo Oblast, Irkutsk Oblast, and Khakassia. However, high transportation expenses, which for some imported coal exceed wholesale prices by several times, negate production efficiency. The tremendous importance of this industry to production and life-sustaining activities of the population explains key investments in its capital assets. However, replacement rates of fixed assets in industry enterprises seriously lag behind the rate of retirement of outdated equipment. Such a situation in a key branch of the economy endangers not only efficient operation of enterprises and organizations, but also the life-sustaining activity of the Amur population. The power sector is an important branch of the regional fuel and energy complex. During the 1990s reforms, there were no major changes in volumes or structure of generating capacity in the Far East (Table 1.14). There was no large increment of electrical power generation beginning in 2004, after the first operational stage of the Bureiskaya hydroelectric power plant at Talakan in Amur Oblast during 2003.

Table 1.14 Electrical power generation in the Amur region (× 109 kWh). (Sources: Regions of Russia 2008; Russia in Figures 2011)

	1990	1995	2000	2002	2004	2006	2007	2010
Far East	47.5	38.5	38.8	38.6	40.1	41.1	40.7	46.6
Share of Amur region in electrical power generation in FE, %	61.7	61.0	78.3	59.6	79.3	86.1	87.8	63.1
Share of Amur region of FE in electrical power generation in the country, %	2.7	2.7	3.5	2.6	3.4	3.5	3.5	2.8
Zabaikalye Territory	3.6	4.5	5.9	5.6	5.8	6.0	6.1	6.7
Share of Zabaikalye Territory in electrical power generation in the country, %	0.3	0.5	0.7	0.6	0.6	0.6	0.6	0.6

The majority of energy in the Far East is generated by thermal-electric power stations, and these are the sole energy producers in Primorsky and Khabarovsk Krais and the Zabaikalye Territory. In the Amur region, a large share of electric energy is produced by hydroelectric power plants (Zeya and Bureya in Amur Oblast). In 2010, 12.8 billion kWh were generated in Amur Oblast, 9.3 in Primorsky Krai, 7.2 in Khabarovsk Krai, 6.7 in Zabaikalye Territory, and 0.1 in the Jewish Autonomous Region. Tremendous opportunities for development of the electrical energy industry in the Amur region are related to cooperation with APR countries, primarily the PRC and the DPRK.

1.3.7 Petrochemical Complex

The petrochemical industry in the region has also seen a considerable decline in production during a period of economic crisis. However, some types of products (sulfuric acid, fuels, and lubrication materials) have maintained production outputs because of consistent demand. The petrochemical industry in Amur is represented by petroleum processing plants at Khabarovsk and Komsomolsk-on-Amur. There, crude oil distillation is carried out and gasoline and industrial fuel oil are produced. Enterprises greatly increased production output in the 2000s (Table 1.15).

In 2010, 11.6 million t of petroleum were supplied to Khabarovsk Krai for refining. The region accounted for 4.6 % of Russian crude oil distillation.

Table 1.15 Product output of petrochemical complex in the Far East (× 10^3 t). (Sources: Khabarovsk Krai. Statistical Yearbook. Khabarovsk: Khabarovskstat 2009)

Production method	2004	2005	2006	2007	2008
Crude oil distillation	8709.4	10,095.0	10,220.6	10,860.0	11,212.7
Benzine including motor one	1619.8 702.2	1932.4 763.1	1963.2 815.3	2011.2 815.9	2087.5 972.0
Residual fuel oil	3386.3	3935.5	39471	4221.9	4416.0

1.3.8 Construction Materials Industry

The construction materials industry in Amur is a service branch of the economy. The industry is traditionally characterized by strong increases in production, caused by high demand for materials in capital construction of all economic branches and in residential construction. However, with the advent of reforms in the 1990s, demand for products from the industry considerably decreased because of declines in all branches of the economy. There was some revival of demand in recent years, related to increases in residential construction (Table 1.16).

Cement production in the Amur region is confined to Spassk-Dalny in Primorsky Krai and Tyoploye Ozero and Landoko in the Jewish Autonomous Region. Precast reinforced concrete structures and workpiece production (PRCS&WP) plus construction brick manufacturing are characteristic of almost all areas in the region. The regional leader in output of these products before 2007 was Primorsky Krai, supplanted later by Khabarovsk Krai. During 1990–2006, regional volumes of PRCS&WP production dramatically decreased. The major causes were a decrease in demand and high production costs. Then prices rose for electrical and heat power. Prospects for development of the construction materials industry in the region are tied to further increases in volumes of residential construction, implementation of large-scale investment projects (e.g., construction of transportation facilities, hotels, and convention halls for the 2012 Asia-Pacific Economic Cooperation Summit in Vladivostok), and increases in cement export to APR markets.

1.3.9 Light Industry

The consumer goods industry in the region has always had a public service function, and has provided employment (generally to women) in eastern areas of the country. The majority of the female population in the Far East and Chita region has mainly worked in the light manufacturing and fishing industries. Local production of commodity goods could not meet demand in the Amur region. The largest production volume of the industry was in garment factories. These were located in all republican or provincial centers of the region and in major cities, such as Ussuriysk, Lesozavodsk, and Spassk-Dalny in Komsomolsk-on-Amur. However, after the 1990s reforms, the consumer market was swamped by inexpensive (and not infrequently low-quality) products from China. This resulted from removal of restrictions on imports of soft goods and a slump in purchasing power of the popular majority. Russian enterprises in the consumer goods industry have not withstood competition from foreign consumer-goods manufacturers, and have had to reduce production (Table 1.17).

For example, fabric weaving in the Amur region is characterized by small volumes, and was represented in Khabarovsk Krai, the Jewish Autonomous Region, and Zabaikalye in Chita. At present, fabric weaving maintains only a small volume in Khabarovsk Krai. There is production of knitted goods in all areas of the Amur

Table 1.16 Production of building materials in the Amur region. (Sources: Regions of Russia 2008)

	1990	1995	2000	2002	2004	2007
Cement production, × 10^6 t						
Far East	4873	1105.6	853.2	1097	1273.3	1431.7[a]
Share of Amur region in cement production in FE, %	90.4	74.9	78.4	76.1	83.5	75.7
Share of Amur region of FE in cement production in the country, %	5.3	2.3	2.1	2.2	2.2	1.8
Precast reinforced concrete structure and work-piece production, × 10^3 m^3						
Far East	4662.1	768.1	405.2	445.2	587.6	658.1
Share of Amur region in precast reinforced concrete structure and work-piece (PRCS&WP) production in FE, %	66.6	66.9	73.6	76.9	73.1	77.1
Share of Amur region of FE in PRCS&WP production in the country, %	3.9	1.8	1.6	1.7	2.0	1.7
Zabaikalye Territory	401.5	63.2	23.6	27.6	37.1	57.0
Share of Zabaikalye Territory in PRCS&WP production in the country, %	0.5	0.2	0.1	0.1	0.2	0.2
Production of building brick, × 10^6 standard bricks						
Far East	864	217	121	142	147	157
Share of Amur region in production of building brick in FE, %	97.8	71.9	99.0	99.1	100	100
Share of Amur region of FE in production of building brick in the country, %	3.5	1.1	1.1	1.3	1.3	1.2
Zabaikalye Territory	187	61.6	27.9	32.4	37.2	130
Share of Zabaikalye Territory in production of building brick in the country, %	0.8	0.4	0.3	0.3	0.3	0.9

[a] Data for 2006

region, but it is most developed in the Jewish Autonomous Region and Primorsky Krai. Shoemaking is most developed in Birobidzhan of the Jewish Autonomous Region and Ussuriysk in Primorsky Krai.

1.3.10 *Food Industry*

As with the consumer goods industry, the regional food industry has the function of providing food products to the public. Therefore, both industries were subjected to the same negative impact from foreign producers. Decline in food product output was also caused by a strong increase in production prime costs from price rises for raw materials, transportation, and electrical and heat energy. At present, there is an increase in production of local consumer goods, and purchasing power

Table 1.17 Output of light-industry products in the Amur region. (Sources: Regions of Russia 2008)

	1990	1995	2000	2002	2004	2006
Production of textiles, × 10^3 m^2						
Far East	5.1	0.3	0.1	0.01	0.04	0.01
Share of Amur region in production of textiles in FE, %	100	100	100	100	100	100
Share of Amur region of FE in production of textiles in the country, %	0.06	0.02	0.004	0.0004	0.001	0.0004
Zabaikalye Territory	23.4	0.4	–	–	–	–
Share of Zabaikalye Territory in production of textiles in the country, %	0.3	0.02	–	–	–	–
Manufacture of knitted goods, × 10^3 pieces						
Far East	31,555	2467	28,593	30,253	26,864	8898
Share of Amur region in manufacture of knitted goods in FE, %	99.2	99.5	99.9	99.9	99.9	99.3
Share of Amur region of EF in manufacture of knitted goods in the country, %	4.1	2.3	23.6	22.9	22.1	2.2
Zabaikalye Territory	12,375	1917	82.4	10	228	325
Share of Zabaikalye Territory in manufacture of knitted goods in the country, %	1.6	0.4	0.07	0.01	0.2	0.3
Shoe making, × 10^3 pairs						
Far East	10,194	712	199	198	1389	1903
Share of Amur region in shoe making in FE, %	89.5	91.4	87.4	73.7	98.5	98.2
Share of Amur region of FE in shoe making in the country, %	2.4	1.3	0.5	0.3	2.9	3.3
Zabaikalye Territory	4666	530	145	103	111	150
Share of Zabaikalye Territory in shoe making in the country, %	1.2	0.9	0.4	0.2	0.2	0.3

of the population is also increasing. However, negative consequences of production decline in the 1990s have been observed in the Amur region to the present (Table 1.18).

The largest enterprises producing food goods are confined to towns, i.e., administrative centers of regional and municipal levels and industrial hubs. Flour and cereal products, meat, oils, fats, wines, and vodka are found in Khabarovsk. Dairy products, meat, oils, and fats are produced in Blagoveshchensk, and oils, fats, dairy products, and granulated sugar are found in Ussuriysk. Confectioner's goods, wines, and vodka are produced in Vladivostok, and dairy products and meat in Chita.

Table 1.18 Output of food industry products in the Amur region. (Sources: Regions of Russia 2008)

	1990	1995	2000	2002	2004	2006
Production of meat including first category by-products, × 10^3 t						
Far East	225.7	58.5	19.0	19.3	28.8	35.7
Share of Amur region in production of meat in the Far East, %	65.9	63.4	71.1	76.9	86.4	91.0
Share of Amur region of FE in production of meat in the country, %	2.3	1.6	1.1	1.0	1.4	1.5
Zabaikalye Territory	50.9	5.7	1.5	0.9	0.9	1.3
Share of Zabaikalye Territory in production of meat in the country, %	0.8	0.2	0.1	0.1	0.1	3.6
Production of whole-milk products, × 10^3 t						
Far East	1070.5	189.3	159.6	171.9	204.7	226.7
Share of Amur region in production of whole-milk products in FE, %	62.2	54.3	73.9	70.0	69.6	71.8
Share of Amur region of FE in production of whole-milk products in the country, %	3.2	1.8	1.9	1.6	1.6	1.6
Zabaikalye Territory	114.3	15.2	8.4	8.9	13.2	13.5
Share of Zabaikalye Territory in production of whole-milk products in the country, %	0.5	0.3	0.1	0.1	0.1	0.1
Butter manufacture, tons						
Far East	13,610	6101	3678	4379	5344	5131
Share of Amur region in butter manufacture in FE, %	65.5	63.9	63.1	42.9	43.4	44.4
Share of Amur region of FE in butter manufacture in the country, %	1.0	0.9	0.9	0.7	0.8	0.9
Zabaikalye Territory	4801	961	251	177	107	55
Share of Zabaikalye Territory in butter manufacture in the country, %	0.6	0.2	0.1	0.1	0.04	0.02
Production of oils, × 10^3 t						
Far East	28.8	12.3	9.1	13.1	16.3	23.7
Share of Amur region in production of oils in FE, %	100	100	100	100	100	100
Share of Amur region of FE in production of oils in the country, %	2.5	1.5	0.7	1.1	0.9	0.9
Zabaikalye Territory	–	0.003	0.002	0.007	0.001	0.001
Share of Zabaikalye Territory in production of oils in the country, %	0.0	0.0	0.0	0.0	0.0	0.0
Production of granulated sugar, ×10^3 t						
Far East	147.3	81.1	74.1	0.03	43.7	141.2
Share of Amur region in production of granulated sugar in FE, %	100	100	100	100	100	100
Share of Amur region of FE in production of granulated sugar in the country, %	3.9	2.6	1.2	0.001	0.9	1.4

1.3.11 Agriculture

The Amur region is predominantly highlands, with agro-climatic conditions that pose difficulties to agriculture. The most favorable conditions are on the plains of Zeya-Bureya, Lower Priamurye, and Khanka. In 2004, 415,300 people in the region were engaged in agriculture, of which 205,900 were in the Far East. In 2008, 303,100 were involved in agriculture, hunting, forest management, fishing, and fish farming in the FEFD. This included 208,700 in the Amur region, or 68.9 % of those employed in the entire Far East and 3.1 % of those engaged in these branches throughout Russia. In the Zabaikalye Territory, 62,900 were engaged in agriculture, 0.9 % of the Russian total.

In 2006, agricultural land area in the FEFD reached 136.8 million ha. There was 7.6 million ha in Amur, or 5.6 % of Far East lands and 1.7 % of all Russia. Of that, cultivated land area of the Far East was only 3.1 million ha. In the Amur region, there were 2.2 million ha, or 71.7 % of cultivated land in the Far East and 1.4 % of such land in the RF. Only 1.6 million ha were arable lands in the Far East; 1.4 million ha of that was in the Amur region, which was 89.6 % of Far East and 1.4 % of Russian arable lands. At the end of 2006, cultivated land in the Zabaikalye Territory occupied 4.7 million ha. This included 546,200 ha of arable lands, or 2.8 % of all cultivated land in Russia and 0.5 % of arable land in the country. Basic cultivated land of the Amur region is concentrated in the south, in Amur Oblast, the Jewish Autonomous Region, and Primorsky and Khabarovsk Krais, constituting 71.7 % of Far East cultivated lands.

In 2010, areas under cultivation on farms of all categories equaled 790,300 ha. This included 25.8 % of cereal crops and 61.3 % of technical crops in Amur Oblast; 314,000 ha including 25.5 % of cereal crops and 44.4 % of technical crops in Primorsky Krai; 217,200 ha including 70.0 % of cereal crops and 18.0 % of forage crops in the Zabaikalye Territory; 108,400 ha including 13.5 % of cereal crops and 66.5 % of technical crops in the Jewish Autonomous Region; and 72,600 ha including 8.8 % of cereal crops, 20.8 % of technical crops, 40.8 % of forage crops, and 30.0 % of potatoes, vegetables, melons and gourds in Khabarovsk Krai.

The socioeconomic reforms of the 1990s resulted in a severe downturn of agricultural production in the Far East, the Zabaikalye Territory, and Baikal region. On farms of all categories, areas of all agricultural crops have greatly declined. For example, in the Amur region of the Far East, these areas decreased from 2,633,300 ha in 1990 to 1,193,700 ha in 2007, a reduction factor of 2.2. This substantially reduced output volumes of crop and animal products (Table 1.19).

The Amur region has greater agricultural potential than northern portions of the Far East. A difficult situation persists for plant growth and cattle breeding in the region. Despite growth of certain factors in the 2000s, regional agricultural production could not attain 1990 outputs of the most important products, such as milk, eggs, and meat. Local production of agricultural goods cannot fully satisfy population demand. To overcome this crisis, regional agriculture should switch to new technologies, raise labor productivity, and reduce production costs (Leonov et al. 2007).

Table 1.19 Output volumes of agricultural products in the Amur region (farms of all categories). (Sources: Regions of Russia 2008)

	1990	1995	2000	2002	2004	2007
Gross grain harvest (in weight after processing), $\times 10^3$ *t*						
Far East	1312.2	488.4	310.9	577.4	269.4	562.7
Share of Amur region in FE cropland acres, %	98.1	96.7	90.9	96.4	93.6	97.7
Share of Amur region of FE in cropland acres in the country, %	1.1	0.7	0.4	0.6	0.3	0.7
Zabaikalye Territory	988.6	389.6	195.6	333.2	115.9	168.3
Share of Zabaikalye Territory in cropland acres in the country, %	0.8	0.6	0.3	0.4	0.2	0.2
Stock of cattle, $\times 10^3$ *head*						
Far East	1709.0	1033.9	666.8	637.3	562.9	498.1
Share of Amur region in FE stock of cattle, %	63.9	56.6	49.5	46.7	43.3	43.0
Share of Amur region of FE in stock of cattle in the country, %	1.9	1.4	1.2	1.1	1.1	0.9
Zabaikalye Territory	801.0	558.4	441.4	435.6	416.3	435.1
Share of Zabaikalye Territory in stock of cattle in the country, %	1.4	1.4	1.6	1.6	1.8	2.0

1.3.12 Industrial Hubs

The regional diversity of socioeconomic and natural-resource factors for establishing enterprises determines differences of industrial hubs, via the following characteristics:

- Specialization of primary production: extractive or processing industries
- Peculiarities of structure formation: enterprises established before 1917 and subjected to reconstruction during the socialist industrialization; those created during the socialist construction; those put into operation during the social and economic reforms
- Size (number of inhabitants or operating personnel, output volume, cost of production assets): large, significant, other.

The Amur region, with the richest territorial combinations of natural resources and extensive capability of extractive facilities, a unique economic-geographic and, most importantly for the country, geopolitical position, operating defense complex, the following types of industrial hubs are characteristic (Fig. 1.2). Large industrial hubs in the region with populations greater than 500,000 emerged as centers of the processing industry as early as the end of the twentieth century in Khabarovsk and Vladivostok. During the socialist industrialization, their structure was greatly extended.

The majority of large-size (populations 100–500,000) and economic-specialization industrial hubs emerged before (Chita, Blagoveshchensk, and others) and

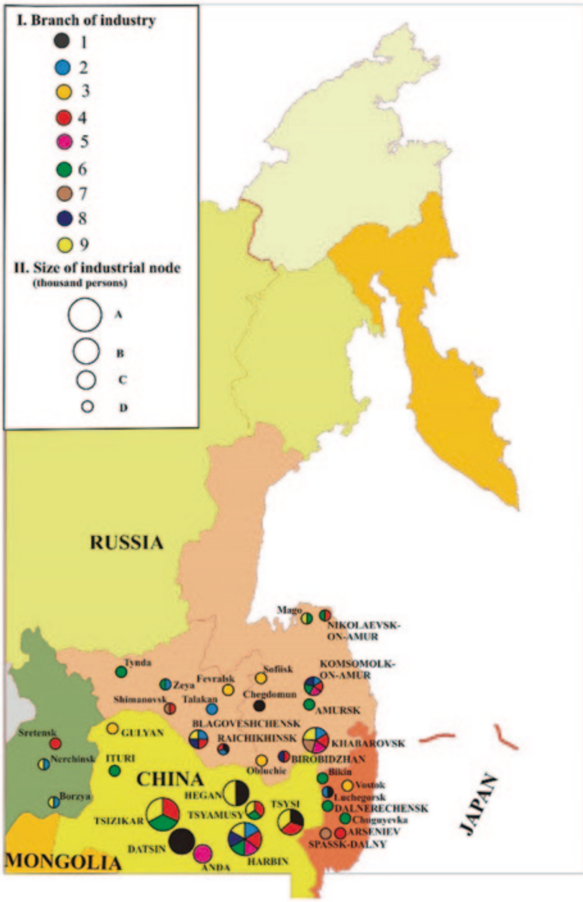


Fig. 1.2 Industrial nodes of Amur region. I. *Branch of industry*: *1* fuel, *2* energy, *3* nonferrous metallurgy, *4* mechanical engineering, *5* chemical industry, *6* woodworking, *7* building materials, *8* light industry, *9* food industry. II. *Population of industrial node (thousands)*. *A* more than 1000, *B* 1000–501, *C* 500–100, *D* less than 100

during the socialist industrialization (Komsomolsk-on-Amur, Amursk, and others). Branches of specialization of these industrial hubs are mainly processing.

Important industrial hubs with a population less than 100,000 were established during the socialist construction, and were based predominantly on exploitation of rich natural resources, e.g., mining, forestry, fisheries, fuel and power. The operating structure of an industrial hub can be portrayed as an aggregate of enterprises in different industries that have various functions, as follows: (1) specialization; (2) services to production; and (3) service to the public within the industrial hub or economic region. Considerable reserves, high-quality extracted resources, low transportation tariffs, economic power of hydroelectric stations, consistent demand for raw materials, and semi-finished goods guaranteed highly efficient production. Under current economic conditions, local territorial-production systems limited to a single geographic location are the predominant type of industrial hub. The structure of these systems consists of several production groups of enterprises and a non-production sphere. Among the industrial hubs, there is a predominance of

Table 1.20 Priority activities in the Amur region (for 2030)

Priority activities	Priority activities in regions					
	Zabaikalye Territory	Amur Oblast	Jewish Autonomous Region	Khabarovsk Krai	Primorsky Krai	∑ estimate
Mining complex (including extraction and processing)	++	++	++	+	+	++
Forestry-based complex (including harvesting and advanced processing)	+	++	+	++	+	++
Oil and gas complex (including transport, processing)	−	+	+	++	++	+
Marine economy complex (including river and sea transport, shipbuilding, fish breeding)	−	+	+	++	+	+
Tourism, including ecological one	+	+	+	++	++	++
Power engineering, including hydroelectric station	+	++	+	++	++	++

− designates a lack of this type of activity, + development of this type of activity, and ++ strong development of priority activities

productive-economic relations that is not as strong as industrial-engineering ones, but these differ because of considerable flexibility. This is more efficient with the fast-changing business situations of sales markets.

Analysis of sectoral and territorial features of the modern functioning of links in inter-sectoral industrial complexes of the Amur region permits identification of major problems and upcoming trends in their development. Consideration of developed strategies of socioeconomic development in the Far East and Baikal regions in 2020, 2030, and 2050 (Ishayev 1998; Melamed 2008; Minakir 2006; Minakir and Prokapolo 2010; Strategy of the Social-Economic Development of Far East and Baikal Region until 2025 2009; Pacific Russia-2030 2010) and our investigations (Baklanov 2001, 2007; Baklanov et al. 2011) permit determination of the following priority lines of development in the Amur region territories (Table 1.20).

High overall estimates characterizing the most favorable conditions for development in the Amur region were found for enterprises of mining, forestry-based complexes, the power generation sector, and tourism (Table 1.20). There are favorable factors for realization of the aforementioned priority types of activities in

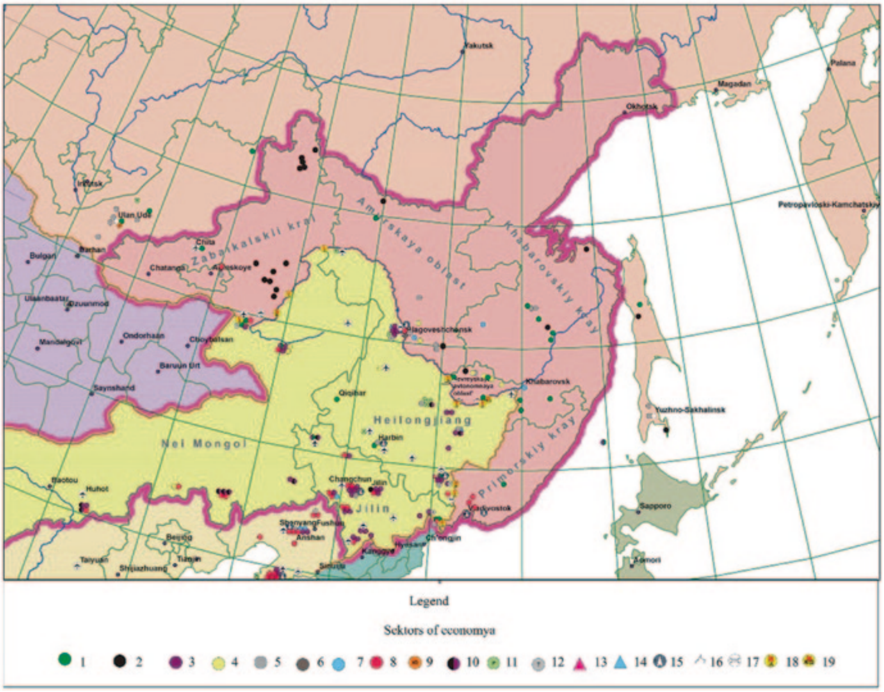


Fig. 1.3 Basic investment projects in the Amur region (for a period through 2030). Economic sectors: *1* forest industry, *2* mining industry, *3* chemical industry, *4* food industry, *5* building industry, *6* construction, *7* energy engineering, *8* machine building industry, *9* jewelry production, *10* metallurgy, *11* tourist-recreation sector, *12* transport and logistics, *13* exhibition centers, *14* trading centers, *15* technological clusters, *16* birthing facilities, *17* bridges, *18* motor transport crossings, *19* railway crossings

the region. These are strong NRP, advantageous economic-geographic positions, and considerable investment in development of Far East infrastructure by federal authorities. These include construction of new trunk roads and bridges, development of projects entailing more effective use of transit opportunities of the Baikal-Amur Mainline and main Trans-Siberian railway, and reconstruction of seaports and airports. Figure 1.3 shows the largest investment projects oriented toward use of the favorable factors of economic activity development in the Amur region. These projects are mainly related to the extraction of commercial minerals, agricultural activities and food production, nonferrous and precious metals, procurement and primary processing of timber, fish harvesting, and seafood. The character and intensity of regional economic exploitation will change accordingly, which should be considered during determination of predictive estimates of land-use dynamics in the Amur River Basin through 2030 (Tables 1.21 and 1.22). Successful completion of the aforementioned investment projects could substantially enhance the economic potential of the Amur region and produce higher living standards.

Table 1.21 Predictive estimates of land-use dynamics in the Amur River Basin (for a period through 2030)

Types	Area, $\times 10^3$ km^2	Change	Predictive estimates of changes			
	1930–1940	2000–2001	Area, 10^3 km^2	Share, in %	Share, in %	Area, 10^3 km^2
Wooded lands	1057.0	945.8	−111.2	−5.5	−6.5	−115
Sparse forests	97.3	145.4	48.1	2.4	3.0	50
Shrubs	68.7	121.6	52.9	2.6	3.5	60
Meadows	351.3	248.7	−102.6	−5.0	−6.0	−110
Plough lands	136.8	346.7	209.9	10.3	15	260
Rice fields	0.5	26.0	25.5	1.2	3.5	55
Wetlands	270.3	140.0	−130.3	−6.4	−10	−160
Lakes and water reservoirs	9.1	13.1	4.0	0.2	1.5	5.0
Populated localities	0.3	2.7	2.4	0.1	1.0	5
Logged areas	2.7	8.7	6.0	0.3	1.5	10
Burnt places	17.4	27.4	10.0	0.5	1.5	15
Mountain tundra	21.1	13.2	−7.9	−0.4	−0.5	−8
Unused lands	7.3	0.8	−6.5	−0.3	−0.5	−7

Table 1.22 Predictive estimates of land-use change in the Russian portion of the Amur River Basin (for a period through 2030)

Types of land use	Russian part of basin, $\times 10^3$ km^2					
	Change, total	Primorsky Krai	Khabarovsk Krai	Jewish Autonomous Region	Amur Oblast	Zabaikalye Territory
Wooded lands	−104.8	−0.4	−49.8	−1.5	−24.6	−28.4
Sparse forests	60.0	−1.2	27.0	0.4	23.4	10.3
Shrubs	48.5	−2.3	23.1	0.6	19.1	7.9
Meadows	−21.6	0.01	1.8	0.3	0.4	−24.2
Plough lands	68.9	6.0	1.2	2.54	22.2	37.0
Rice fields	2.4	1.7	0.5	0.2	0	0
Wetlands	−60.6	−4.0	−10.2	−2.4	−37.6	−6.3
Lakes and water reservoirs	1.6	0.01	−1.32	0.0	2.0	0.8
Populated localities	0.8	−0.03	0.3	0.03	0.1	0.4
Logged areas	4.0	−0.5	4.1	−0.05	−0.2	0.6
Mountain tundra	−60.6	−4.0	−10.2	−2.4	−37.6	−6.3
Unused lands	1.6	0.01	−1.32	0.0	2.0	0.8

1.4 Conclusion

A diversified multi-sector economy has formed in the Amur River Basin, including mining of various metals, coal, energy and hydro energy production, forestry and agriculture, certain processing branches, engineering, light industries and food industries, tourism and recreation. All kinds of transportation are represented, including railway and automobile, aviation, and water surface, as well as "river-ocean" logistics from the Amur River to the Seas of Okhotsk and Japan. Pipeline transport has been rapidly developed recently in both the Russian and Chinese territories of the region, where most of the Eastern Siberia–Pacific Ocean oil pipeline with embranchment to northeastern China and a segment of the Sakhalin–Khabarovsk–Vladivostok gas pipeline are located.

All these activities coupled with relevant infrastructure and settlements form diversified territorial structures of nature management. The latter consist of lands where natural resources are extracted directly, such as metal ores, coal, and wood. This occurs on land, farmland, industrial sites, settlements, and zones where there are various nature–human interactions. These are represented as nodular forms in mining areas, areas of settlements and large enterprises, as linear forms along highways and rivers, and as areal forms such as large forestry, agriculture, and nature conservation areas. In many cases, separate territorial structures of nature management and its links overlap and combine. For instance, mining nodes in forest, settlements nodes in farmland, transportation lines in forest and farmland, linear and node combinations are connected by linear links.

One can calculate the value of natural resource use and indirect resource consumption as decreases of natural resource potential caused by technological impacts, including those in extraction of natural resources for all related territorial structures of nature management. Such calculations and assessments can be a basis for a balance model of regional nature management that can be used for measuring predicted variants of regional development. In the Amur River Basin as a whole, considerable socioeconomic development is expected in the long term. Several planned investment projects in both the Russian and Chinese territory for extraction and processing of local natural resources, energy production, transport construction (including oil and gas pipelines), forestry, and agriculture will form new territorial structures of natural resources management and its links. In the framework of the proposed approach, it is advisable to assess the effectiveness of new territorial structures of nature management and the rebuilding of existing ones.

References

Baklanov PYa (2001) Far-Eastern Region of Russia: problems and opportunities of sustainable development. Dalnauka, Vladivostok

Baklanov PYa (2007) Territorial structures of economy in the regional management. Nauka, Moscow

Baklanov PYa, Ganzei SS (2008) Transboundary territories: problems of the sustainable development. Dalnauka, Vladivostok

Baklanov PYa, Moshkov AV, Romanov MT (2011) Territorial structures of economy and economic districts in the long-term development. Bull Far East Branch RAS 2:18–28

Goskomstat (2008) Russian statistical yearbook. Rossii, Moscow

Goskomstat (2011) Russia in figures. Rossii, Moscow

Government of RF (2009) Strategy of social and economical development of Far East and Baikal Region until 2025. Government of RF on Dec 28, 2009 (No. 2094-p) Official web-site of Khabarovskii Krai Government. http://gov.khabkrai.ru/invest2.nsf/General_ru/14FDCF99A4F6EEFACA25766B0024C2E5. Accessed 15 April 2010

Industry of Russia (2002) Goskomstat. Rossii, Moscow

Industry of Russia (2010) Goskomstat. Rossii, Moscow

Ishayev VI (1998) Strategic planning of regional economic development. Dalnauka, Vladivostok

Khabarovskii Krai Statistical yearbook office (2009) Khabarovskii Krai statistical yearbook. Khabarovskstat, Khabarovsk

Leonov SN, Korsunsky BL, Barabash ES (2007) Regional economy and management: economy of the Far East. Dalnauka, Vladivostok

Melamed II (2008) Strategy of development of the Far East of Russia. Modern Economy and Law Publisher, Moscow

Minakir PA (2006) Economy of regions of the Far East. CJSC Publishers “Ekonomika”, Moscow

Minakir PA (ed) (2010) Pacific Russia–2030: scenery prediction of regional development. FEB RAS, Khabarovsk

Minakir PA, Prokapolo OM (2010) Regional economic dynamics of the Far East. FEB RAS, Khabarovsk

Moshkov AV (2005) Industrial hubs of the Far East. Dalnauka, Vladivostok

Primorye in the Far-Eastern Federal District office (2010) Statistical bulletin 2009. Primorskstat, Vladivostok

Regions of Russia (2008) Social-economic indicators in 2007: statistical survey. Goskomstat Rossii, Moscow

Tkachenko GG (2009) Territorial differentiation of the NRP of a group of the North-East Asia countries. Geogr Nat Resour 2:12–18

Chapter 2
Land-Cover Change and Climate Change Analysis of the Amur River Basin Using Remote Sensing Data

Yoshitaka Masuda, Shigeko Haruyama and Akihiko Kondo

Abstract We used remote sensing data to clarify recent climate changes and land-cover changes in the Amur River Basin. We also analyzed locations of remarkable land-cover and land-use changes that are of concern for their socioeconomic impacts on fluvial geomorphology. We focused especially on wetlands on the fluvial plain along the Amur River main stem. Land-cover changes in Northeast China are more extensive and rapid than those in Russia and related with land degradation in the north. Rapid land-cover changes have had notable effects on surface erosion and land degradation where is repeated flooding of branches of the Amur River in Northeast China.

Keywords Remote sensing • CRU TS • Amur river • Land-cover change

2.1 Introduction

Local environmental changes originating from rapid land-cover change have been occurring recently in the Amur River Basin. For instance, agricultural development has led to increases in degradation of wetland habitat for migratory birds and fishes, sedimentation of rivers from sloping fields, chemical loading of rivers, and air pollution by forest fires. Biodiversity has decreased in the lower part of the basin. In the Chinese part of the basin, government projects have expanded farming districts. The forest area has been decreased in recent period (Zhang 2000; Ganzey 2005). Cultivated area increased in the 1980s and 1990s, and there are several urban expansion with

S. Haruyama (✉)
Graduate School of Bioresources, Mie University, 1577 Kurimachiyacho, Tsu, Mie Prefecture, Japan
e-mail: haruyama@bio.mie-u.ac.jp

Y. Masuda
NTT Communications Corporation, Tokyo, Japan

A. Kondo
Center of Environmental Remote Sensing, Chiba University, Chiba, Japan

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_2

urban sprawl along the Amur River after 1990s in Northeast China (Liu et al. 2001; Luo 2001; Deng et al. 2001; Doi and Zhang 2001; Ganzey 2005; Haruyama 2005; Haruyama et al. 2010; Murooka et al. 2007a), and paddy fields there have become an important Chinese national food production zone in Northeast China (Motoki 2001). The Sanjiang plain is also "grain cradle of China" and there are large grain granaries in this plain. However, the creep and soil erosion are suddenly occurred after torrential rainfall in Sanjiang Plain because of its weak resilience of land cover function.

In contrast, the Russian part of the basin has been in a state of economic depression since the collapse of the Soviet federation. Therefore, regional differences between the Chinese and Russian parts of the Amur Basin are remarkably profound. Today, natural disasters such as basin wide floods, creep and gulley on the slope land, surface soil erosion, slope collapse, land degradation, increased sedimentation in the river bed, and rapid changes of river course are strongly affected by this uneven distribution of environmental degradation. The land surface disturbances affected the circulation in the Amur-Okhotsk system by analyzing of Iron distribution in the river water and sea water in the Sea of Okhotsk (Shiraiwa 2005;Himiyama 2001; Murooka et al. 2007b; Yamagata et al. 2007; Haruyama et al. 2014). Haruyama et al. (2013) explained that wetlands in the Amur River flood plain are important flood retarding zones or buffer zones for ephemeral inundation under the torrential rainfall in monsoon summer and calculated the peak cut off volume of the severe flooding in the middle reaches of the Amur River Basin. The principle of spatial deviation should be understood when planning mitigation and conservation activities.

The purposes of our study are to: (1) survey land degradation in the Amur River Basin; (2) climate change clarification using CRU TS; (3) determine zones of especially severe land-cover change during the last 20 years; and (4) evaluate principal influences on land-cover and land-use change in the basin with land degradation. We primarily used remote sensing data, with additional analyses of individual regions. By using the Normalized Difference Vegetation Index (NDVI) to map the area, we were able to pinpoint regions undergoing marked land-cover change and to explore trends of these changes.

2.2 Geographic Setting of Study Area

The Amur River flows westward from its headwaters before turning in a large arc to flow east toward the Sea of Okhotsk. The river is joined by the Ussury River, which flows northward, near Khabarovsk, and by the Songhua River, which flows northeastward, near the Sanjiang Plain. The Amur separates into several branches near its mouth, such as the Sungari (Songhua), Zeya, Ussury, Shilka, Argun, and Bureya rivers. Mean discharge of the Amur at Khabarovsk observation station was 330 km^3/year from 1970 to 1995 (Tachibana 2003). The river surface is usually frozen in winter, and discharge peaks in early spring owing to snowmelt and in summer from heavy rainfall.

Tectonic evolution of the Amur River Basin took place during the Mesozoic and Cenozoic eras. There is Paleozoic Mongol-Okhotsk folding structure in the north western area of the Amur River Basin with numerous large faults. The southern Amur Basin is situated on the Bureya and Khanka massifs where are fragmented Chinese platform. The eastern Amur Basin is within the Sikhote-Ali folding area (Makhinov 2010). The geomorphology appears to have been stable during the Holocene; however, in recent years, slope erosion and riverbank erosion of the main river course have been common. The western part of the basin is mountainous, reaching more than 1000 m above sea level, and the fluvial plains with altitudes below 100 m are around the Sanjiang Plain. Peat wetlands are in floodplains and valley floors in the hilly country south of the Amur River. The narrow flood plain continues to the mouth of the Amur and there are swampy are after passing though Khabarovsk. In the city of Harbin, the annual mean temperature is 4.6 °C, and the mean temperature in January is −20 °C and the water surface of the river is frozen in winter (China Map Office 2004). Rainfall concentrates in summer and one crop is planted each year in the basin (Lin and Hasegawa 2005).

Ganzey (2005) explained that the coniferous forest is patched around low mountain ranges, mixed and deciduous forests are mainly located in gentle slope hills and mountain area. The wide grass land and scrubs are in Mongolia territory, however, the above mentioned vegetation has been decreased and changed to agriculture development area.

2.3 Data

2.3.1 Satellite Data

Our remote-sensing dataset was acquired by the Advanced Very High Resolution Radiometer (AVHRR) on the Pathfinder satellite. The Pathfinder AVHRR Land dataset for 1982 through 2000 from the National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC, http://daac.gsfc.nasa.gov) was analyzed for recent land-cover change in the Amur Basin (Fig. 2.1). Climate Research Unit Time Series (CRU TS) Dataset 2.0 that is important data set for analysis of climate change in the Amur River Basin was applied to the temperature and precipitation trends.

The AVHRR sensor measures emitted and reflected radiation in five channels of the electromagnetic spectrum: channel 1 (visible light, 0.58 – 0.68 μm), channel 2 (near-infrared, 0.725–1.1 μm), channel 3 (mid-infrared, 3.55–3.93 μm), channel 4 (thermal infrared, 10.5–11.5 μm), and channel 5 (thermal infrared, 11.5–12.5 μm). Channel 3 is used for sea surface temperature mapping and is not available in the PAL data. Radiances from channels 4 and 5 depend on surface temperature and can be used to map that temperature on a global basis. This dataset divides the year into 36 seasons of 10 days each. The 10-day composite data from the data removes the effects of clouds by choosing observations on cloud-free days. The Interrupted Goode Homolosine Projection used for this data must be converted to

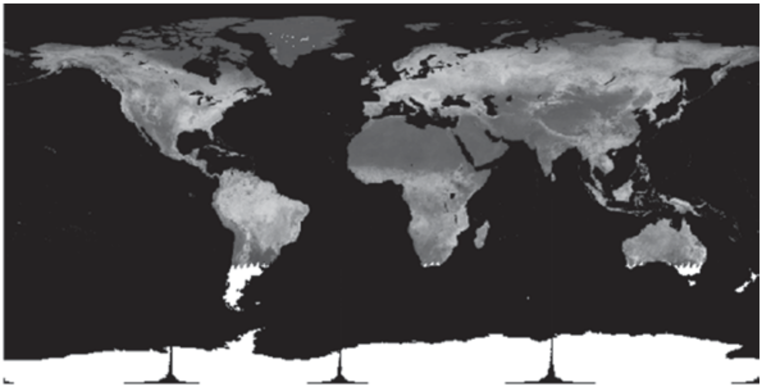


Fig. 2.1 NOAA/AVHRR PAL data. PAL NDVI data converted to equal angular projection from the interrupted goode homolosine projection

an equal-angle projection so that pixel latitudes and longitudes can be determined. Therefore, the spatial resolution was converted from 8 km to 0.1° (about 10 km on the map) of both latitude and longitude, using a tool provided by NASA/GSFC.

AVHRR channel 1 is a part of the spectrum in which leaf chlorophyll absorbs incoming radiation, and channel 2 is a region in which spongy mesophyll leaf structure generates considerable reflectance. These two channels can therefore be used to derive information on vegetative land cover via the NDVI. The NDVI value, which is related to the density and active growth of green vegetation, is calculated from differences in spectral reflection of chlorophyll in the visible light and near-infrared ranges (Myneni et al. 1997; Kondoh et al. 2005; Nemani et al. 2003). The NDVI has been shown to be strongly correlated with vegetation parameters such as land cover and land use (Sannier et al. 1998), green leaf area index (LAI) (Spanner et al. 1990), and green-leaf biomass (Box et al. 1989), and is of considerable value for vegetation discrimination. Myneni (1995) provided a theoretical interpretation between LAI and vegetation. Wang et al. (2005) suggested that NDVI-LAI relationship can vary both seasonally and inter annual in tune with variations in phonological development of the trees and in response to temporal variations of environment. Tucker (1979) suggested the different spectral vegetation indices derived from remote sensing NDVI has been the widely used. The NDVI is the most widely used vegetation index, and is calculated from PAL data by

$$NDVI = \frac{Ch.2 - Ch.1}{Ch.2 + Ch.1}$$

The NDVI equation produces values between 1.0 and −1.0, where positive values indicate green vegetation and negative ones non-vegetated surfaces such as water, barren land, ice, and snow.

Fig. 2.2 Salt marsh; surrounding area converted to corn fields and industrial zones

Fig. 2.3 Harbin (urban expansion) with the Songhua river

Fig. 2.4 Wetlands and paddy field

Fig. 2.5 Water surface of Amur and Songhua rivers (turbid water is the Songhua river)

2.3.2 Land-Use Pattern Corroboration of Remote Sensing Data

The amount of agricultural land in Northeast China that in remote sensing data was irrigated between 1980s and 2000s, was determined from the Heilongjiang Province Statistical Yearbook (2001). The area sown with four main commercial crops such as rice, wheat, corn, and soybeans, between 1978 and 2000, along with patterns of production transition for remote sensing data, were determined using the other local-level statistical materials. The Sanjiang Plain is important signal of recent land use change (China Statistics Office 2001; Haruyama 2005; Haruyama et al. 2010, 2014). The sizes of paddy and upland crop fields in the province were determined by questionnaires administered by local officials. The social background of agriculture development with surface water and underground water utilities was surveyed and we conducted questionnaire survey how is affected by the agriculture engineering adaptation in the Heilongiang Province. We organized field investigations in which we used GPS system to record land cover factor on the Sanjiang Plain, Songnen Plain, and around Khabarovsk Krai in 2002–2006 (Figs. 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, and 2.9).

Fig. 2.6 Cornfields (artificial slope land around hillside)

Fig. 2.7 Paddy fields with irrigation and drainage in the three-river plain

Fig. 2.8 Soybean fields and soil erosion around hillside

Examples of field observation photos from numbered locations are given in Figs. 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, and 2.9. Figure 2.2 shows a typical salt marsh where the surrounding area was being converted to corn fields and industrial zones. Figure 2.3 of Harbin city area shows urban sprawl and development with rapid building construction, as is common in this region. The river is flying river bed after construction of embankment. Figure 2.4 shows a typical wetland landscape, one of several types of wetlands that are being converted to farmland in the Harbin urban expansion area. Figure 2.5 shows sediment in river water at the confluence of the Amur and Songhua river basins, which originates from agricultural development and slope erosion in Northeast China. Figure 2.6 shows a typical cornfield landscape on Sanjiang Plain in which the original forest is almost gone. Figure 2.7 shows rice fields on the floodplain, with irrigation and drainage channels. Figure 2.8 shows soybean fields on old ruggedness mountain and hill escarpment area in Northeast China. We used these photographs of the landscape and land-use conditions as 254 ground truth points during our analysis of remote sensing data.

Local environmental change is affected by global long-term climate change and strongly by recent human activities as short-period environmental change. The rapid agriculture development of flood plain and hill slopes with cutting forest are both factors for soil erosion and creep of the hill slope. To quantify recent climatic changes in our study area, we analyzed portions of the Climate Research Unit (CRU) time series (TS) dataset 2.0. The CRU TS data are supplied on a 0.5—degree grid covering the global land surface. The dataset provides monthly data on cloud cover, diurnal temperature range, precipitation, temperature, and vapor pressure for the period 1992–2000. For our purposes, long term precipitation and temperature

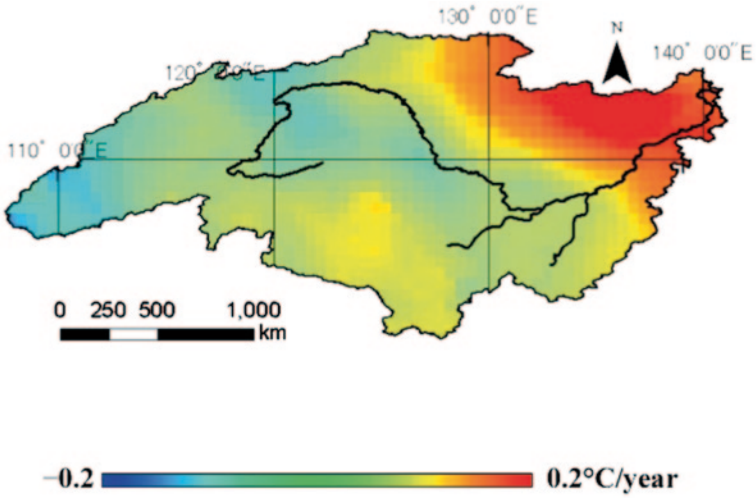


Fig. 2.9 Secular trend of mean temperature in January using CRU TS from 1982 to 2000

data are the most useful of these. We analyzed mean monthly temperatures between 1981 and 2000, annual mean temperatures between 1961 and 2000, monthly precipitation between 1982 and 2000, and yearly precipitation between 1961 and 2000 to detect and characterize long-term climatic changes related to land-cover change issues.

2.4 Land-Cover Change Analysis

Kondoh (2004) analyzed river basin-scale vegetation change and land-cover changes from 1982 to 2000 in the PAL dataset and we derived land-cover change trend over the entire Amur River Basin using this method. Haruyama et al. (2014) explained that he result of each NDVI factor of continuous land cover change in last 20 years. After that, we reanalyzed the same data with CRU TS used the following four quantities: the sum of NDVI (ΣNDVI) during the year, maximum NDVI ($NDVI_{max}$), standard deviation of ΣNDVI ($NDVI_{std}$), and the trajectory of the surface temperature—NDVI scatter chart (TRJ) (Nemani and Running 1997; Price 1984; Haruyama et al. 2014). $NDVI_{max}$ is a widely used for analysis of vegetation activities and reliable index related to maximum leaf area index (LAI) or maximum biomass. LAI is an important biophysical influencing land cover processes (Bonan 1993). We extracted the maximum NDVI for each year and examined its trend during our 19-year analysis period. ΣNDVI is an index that corresponds to annual biomass, as confirmed by Goward et al. (1985) and Box et al. (1989). ΣNDVI was calculated by

$$\sum NDVI = \sum_{i=1}^{N} a_i,$$

where a_i is the NDVI value of a (10-day) season and N is the number of seasons (36). The threshold between vegetated and non-vegetated land is commonly chosen at NDVI = 0.1. Pixels with NDVI less than 0.1 were excluded from our calculations.

We selected $\mathrm{NDVI_{std}}$ as an index of vegetation disturbance, because it indicates the biomass increase and decrease in a year owing to forest fires, floods, and similar events. The standard deviation of ΣNDVI was also derived for these years in our study period. The $\mathrm{NDVI_{std}}$ was calculated by the following:

$$\mathrm{NDVI_{std}} = \sqrt{V_x} \qquad V_x = \frac{1}{19}\sum_{i=1982}^{2000}(x_i - \bar{x})^2 \qquad \bar{x} = \frac{1}{19}\sum_{i=1982}^{2000} x_i$$

x_i is the value of ΣNDVI from 1982 to 2000 and V_x is its variance. For instance, both ΣNDVI and $\mathrm{NDVI_{std}}$ vary throughout the year in regions where floods and forest fires are frequent, as well as in regions where the timing of snowmelt strongly affects vegetation growth.

The TRJ index, which shows the direction of land-cover change, differs with vegetation type (Nemani and Running 1997). For example, TRJ is positive when land cover changes from meadow to bare ground or barren land, and it declines when meadow changes to forest. TRJ is obtained from the scatter chart of surface temperature (Ts) and NDVI, with NDVI on the horizontal axis and Ts on the vertical. Ts is calculated by

$$Ts = Ch.4 + 3.3 \times (Ch.4 - Ch.5)$$

With two channels of thermal infrared data (4 and 5), the split window method of Price (1984) was used to calculate Ts. Therefore, the atmospheric influence was almost entirely corrected. Ts values lower than −100 °C were treated as error pixels and assigned error number zero.

TRJ is derived by calculating the inclination of the recurrence straight line after NDVI, and Ts data of 36 seasons are plotted. TRJ was calculated by

$$TRJ = \frac{\sum_{i=1}^{N}(a_i - \bar{a})(b_i - \bar{b})}{\sum_{i=1}^{N}(a_i - \bar{a})^2} \qquad \bar{a} = \frac{1}{N}\sum_{i=1}^{N} a_i \qquad \bar{b} = \frac{1}{N}\sum_{i=1}^{N} b_i,$$

where b_i is the Ts value of a season. If NDVI is less than 0.1 and Ts less than −100 °C, the pixels are excluded.

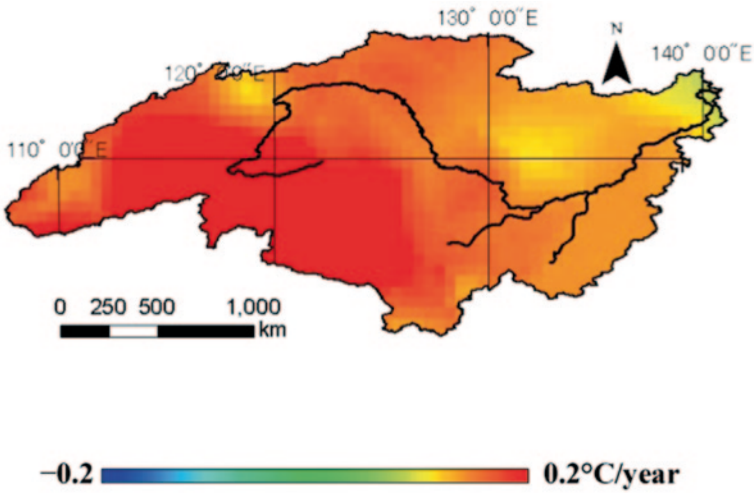


Fig. 2.10 Secular trend of mean temperature in February using CRU TS from 1982 to 2000

Land-cover change can be calculated by applying a straight line to the tracks for every year and analyzing the change of line inclination over the 19-year period. Trends of each parameter (TRJ, ΣNDVI, and $NDVI_{max}$) were calculated via

$$Trend = \frac{\sum_{j=1982}^{2000}(c_j - \bar{c})(d_j - \bar{d})}{\sum_{j=1982}^{2000}(c_j - \bar{c})^2} \qquad \bar{c} = \frac{1}{19}\sum_{j=1982}^{2000}(j - 1982) \qquad \bar{d} = \frac{1}{19}\sum_{j=1982}^{2000} d_j$$

where, j is the value of a given year and d_i is substituted with each parameter (TRJ, ΣNDVI, and $NDVI_{max}$).

Validity of this data results was verified by statistical material analysis and ground truth data from our field investigation; thus, areas with the greatest artificial land alteration were determined.

2.5 Results and Discussion

2.5.1 Climate Research Unit Time Series (CRU TS) Dataset 2.0 Analysis

Figures 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16,2.17, 2.18, 2.19, and 2.20 shows the secular trend of mean temperature between 1982 and 2000 for the 12 calendar

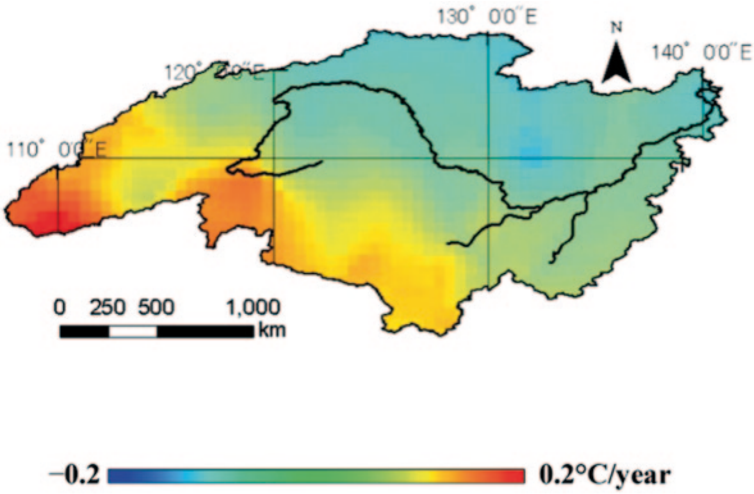


Fig. 2.11 Secular trend of mean temperature in March using CRU TS from 1982 to 2000

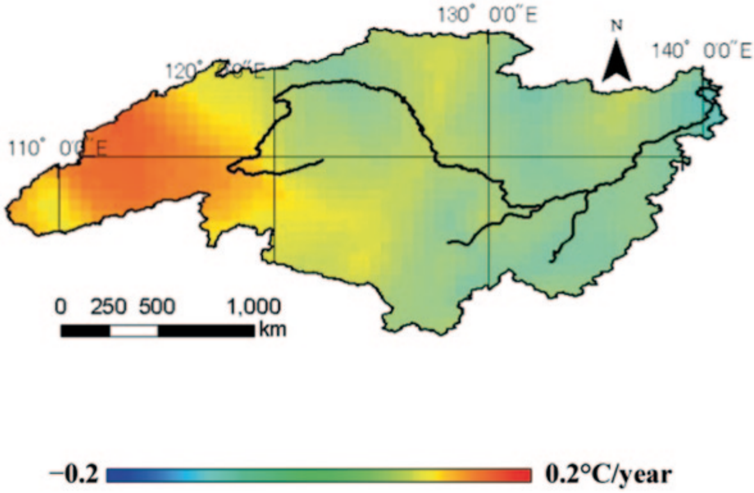


Fig. 2.12 Secular trend of mean temperature in April using CRU TS from 1982 to 2000

months. Figures 2.21 and 2.22 shows the trend of annual mean temperature for two periods, 1961–1990 and 1982–2000 respectively, after trend analysis using the data of CRU TS 2.0 dataset. Our results show that annual mean temperature rose by 0.05 °C/year from 1961 to 1990 and by 0.07 °C/year between 1982 and 2000, especially in the southwest part of the Amur River Basin (Figs. 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, and 2.23). Mean tem-

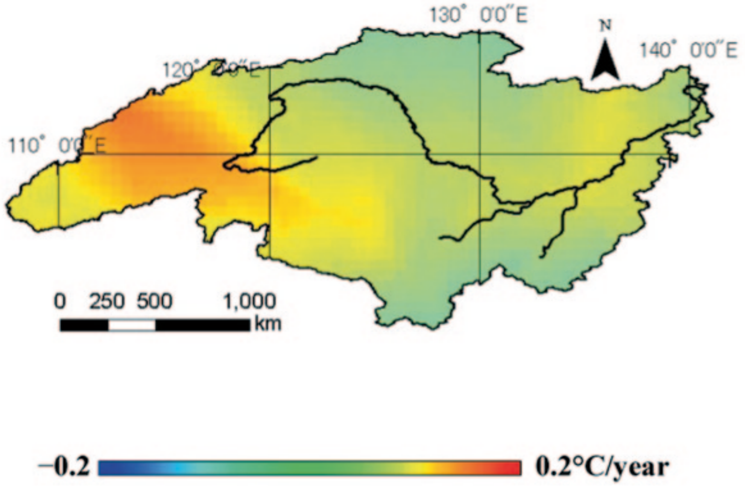


Fig. 2.13 Secular trend of mean temperature in May using CRU TS from 1982 to 2000

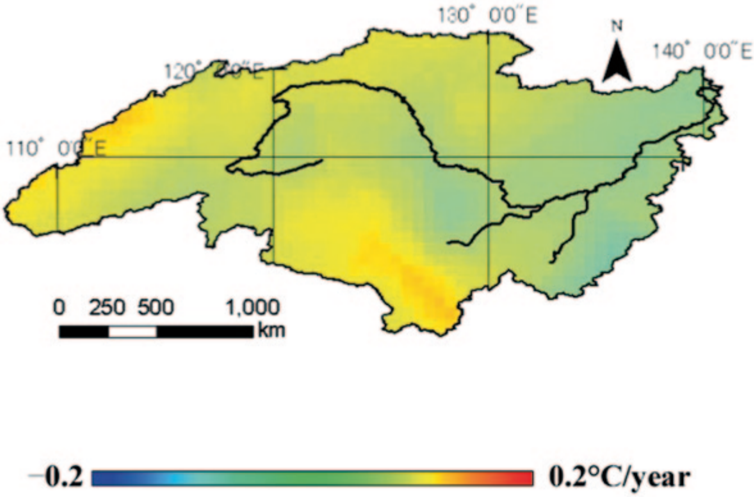


Fig. 2.14 Secular trend of mean temperature in June using CRU TS from 1982 to 2000

perature in February rose substantially across the entire basin. Mean temperature increased in the northern basin in October but fell in November and December. The rise in temperature during early spring may hasten snow and ice melt. This could extend the growth period for specific vegetation.

Figures 2.23, 2.24, 2.25, 2.26, 2.27, 2.28, 2.29, 2.30, 2.31, 2.32 and 2.33, 2.34, 2.35, and 2.36 show the secular trend of precipitation for each month from 1982 to

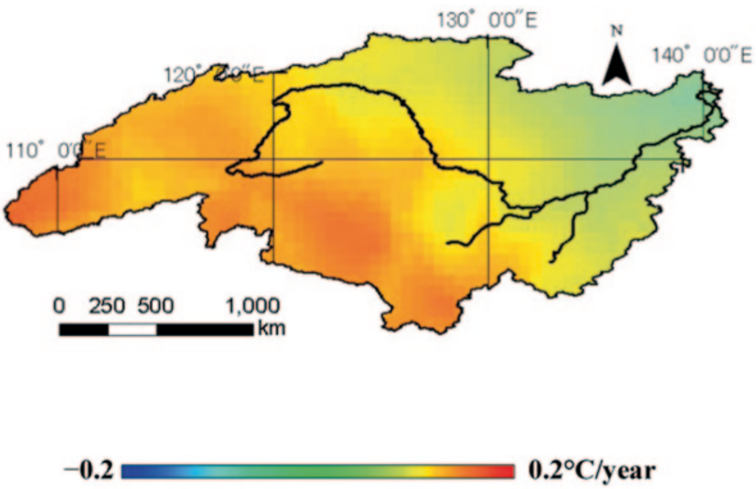


Fig. 2.15 Secular trend of mean temperature in July using CRU TS from 1982 to 2000

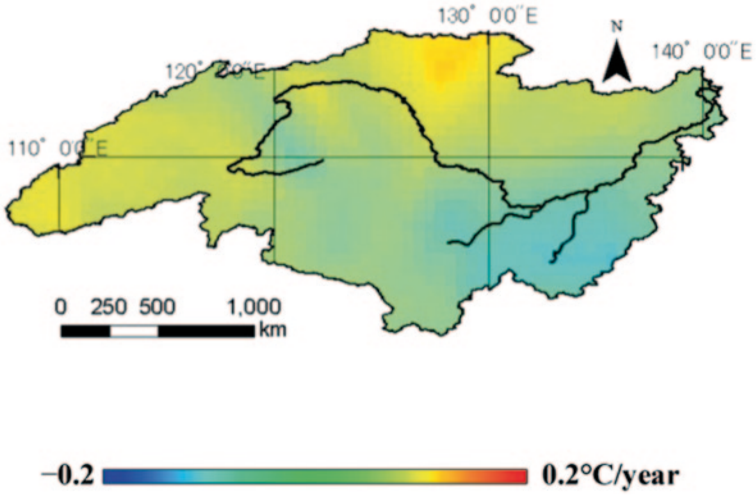


Fig. 2.16 Secular trend of mean temperature in August using CRU TS from 1982 to 2000

2000, and Figs. 2.35 and 2.36 show trends of yearly precipitation for 1961–1990 and 1982–2000. Average annual precipitation increased by 7 mm/year east of Khabarovsk in 1961–1990, but decreased there by 10 mm/year from 1982 to 2000. Annual precipitation increased by 7 mm/year north of the Amur River during 1982–2000. The most dramatic change in monthly precipitation during 1982–2000 was a 5 mm/month rise in August in the northern Amur Basin. However, temperature is a limiting factor on vegetation growth in this area (Olson et al. 1983).

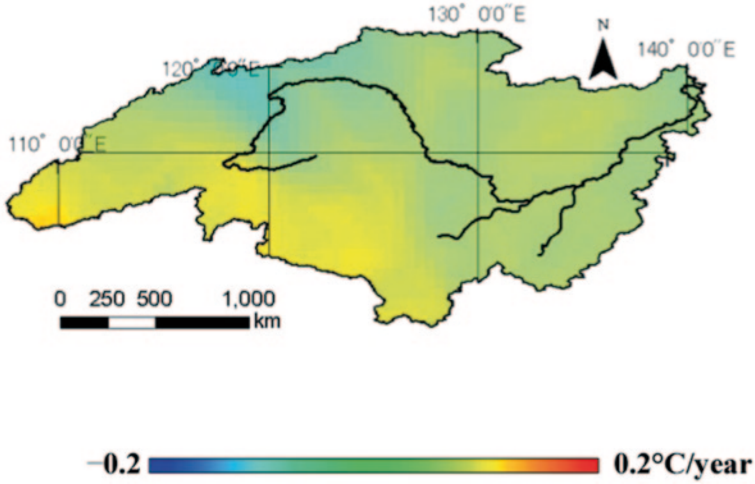


Fig. 2.17 Secular trend of mean temperature in September using CRU TS from 1982 to 2000

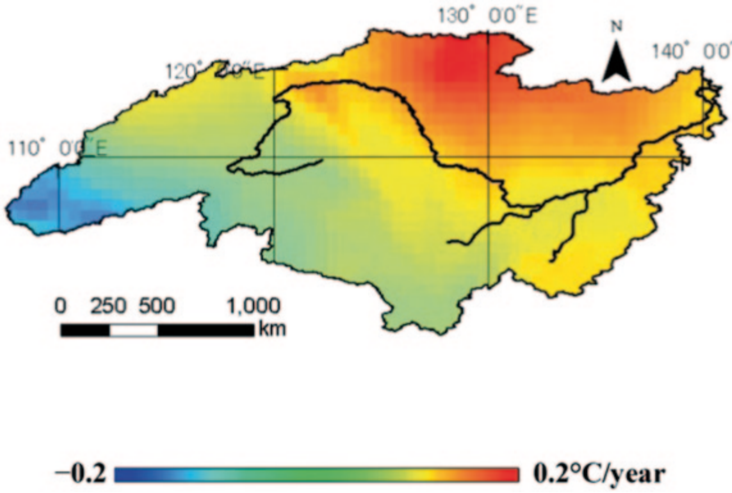


Fig. 2.18 Secular trend of mean temperature in October using CRU TS from 1982 to 2000

2.5.2 Land-Cover Change and CRU TS

The trend of each NDVI value change on the low-relief plain was much less than that in the eastern highlands. The northern region where NDVI was very low in 1983 and 1996 is also remarkable, showing large inter annual changes. However, it is difficult to determine the changes of land cover only from these figures. The fol-

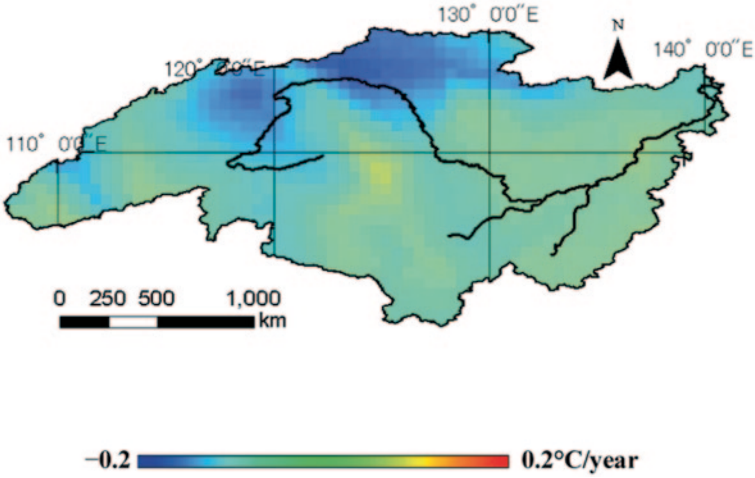


Fig. 2.19 Secular trend of mean temperature in November using CRU TS from 1982 to 2000

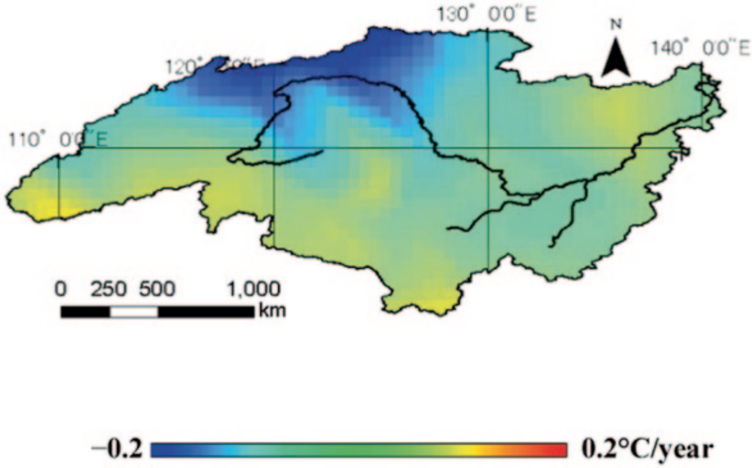


Fig. 2.20 Secular trend of mean temperature in December using CRU TS from 1982 to 2000

lowing subsections discuss each of the areas outlined in Figs. 2.37, 2.38, 2.39, and 2.40 with the result of trend analysis of CRU TS.

Comparing with the land use change trends between China and Russia, the secular trends of each NDVI factor are remarkable in China but the trends in Russia is not remarkable and same as last 20 years. In our ground inspection of the river bed, the most representative change areas and land degradation areas is in Eastern Area of the Amur River Basin and surrounding of Harbin urban expansion area. Agricul-

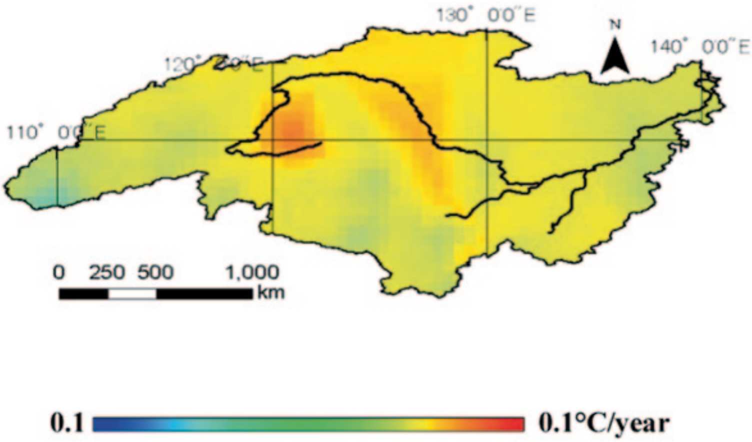


Fig. 2.21 Secular trend of annual mean temperature using CRU TS from 1961 to 1990

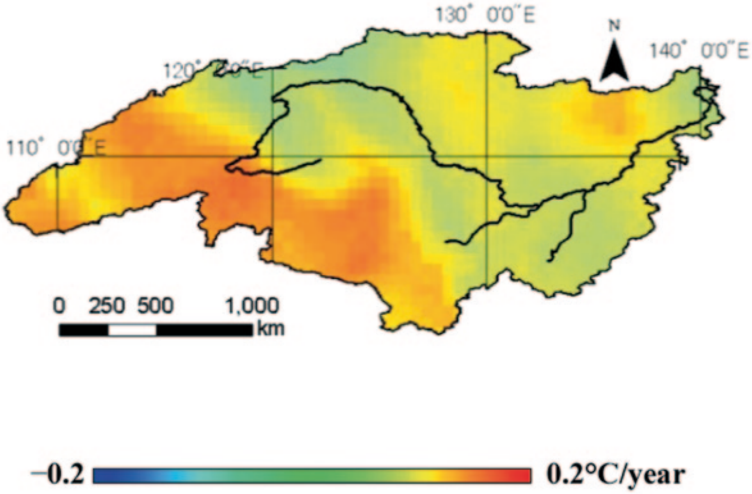


Fig. 2.22 Secular trend of annual mean temperature using CRU TS from 1982 to 2000

tural statistics for areas of Harbin urban expansion and the Sanjiang Plain may be representative of artificial land-use change in the entire Amur Basin. These regions are the most important food production regions or "a cradle of grain" in China. Contrasting to Chinese territory, agriculture development stopped and swamps with peat lands widely remain in Russian territory. However, the wildfire occurrence related with few precipitation disappeared broad forest in Russian territory. This wildfire is one of land degradation functions in this area.

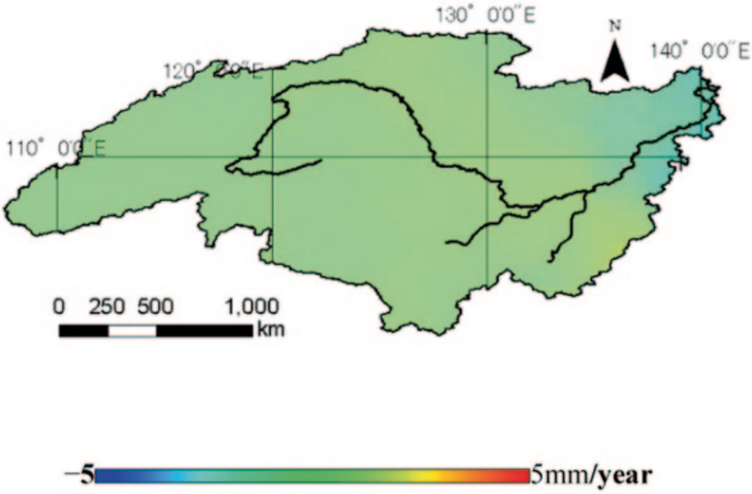


Fig. 2.23 Secular trend of mean precipitation in January using CRU TS from1982 to 2000

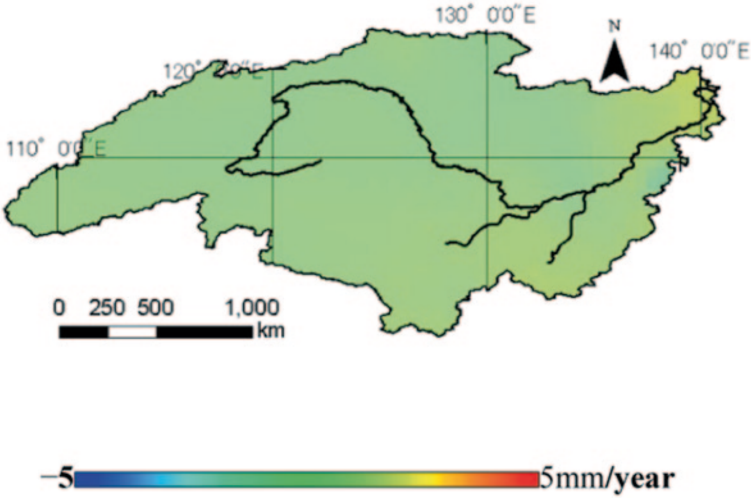


Fig. 2.24 Secular trend of mean precipitation in February using CRU TS from 1982 to 2000

The area of Heilongjiang Province under irrigation and drainage system more than tripled from 1980 through 2000 (Tables 2.1 and 2.2). The agricultural engineering infra-systems have been introduced and supported to new agriculture technology to Chinese farmers living in this province by Siranego Water Users Associations in Niigata Prefecture and Mr. Hara (Agrarian) from Hokkaido in last 30 years. In the last 30 years, the area sown with commercial crops increased by 750 %, and

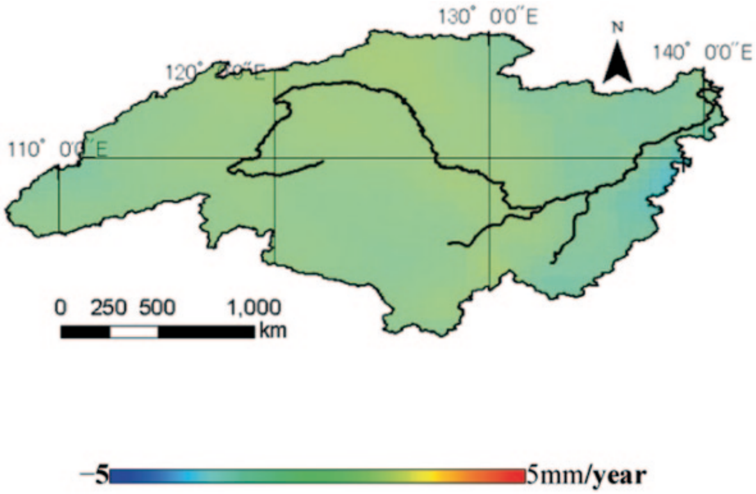


Fig. 2.25 Secular trend of mean precipitation in March using CRU TS from 1982 to 2000

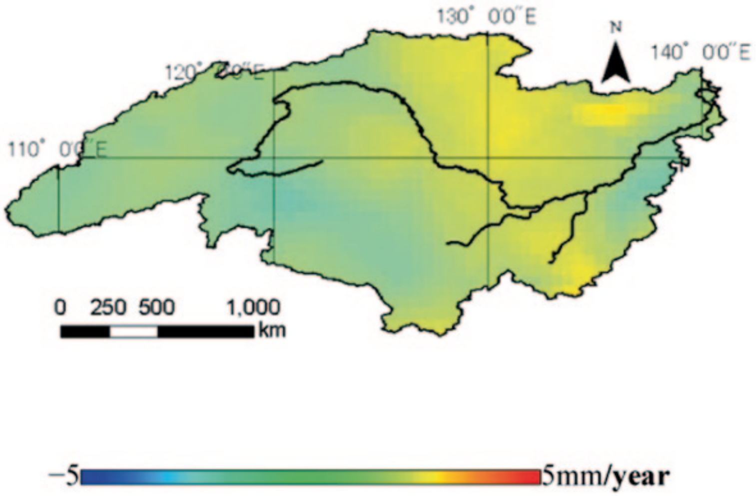


Fig. 2.26 Secular trend of mean precipitation in April using CRU TS from 1982 to 2000

rice production grew by 1460 % supported by planting method introduced by Mr. Hara. The increase of corn production was especially remarkable in the early 1990s (Table 2.3) with agricultural mechanization and fertilizer. Rice production rose with a rapid increase of agricultural development and irrigation channels beginning in the late 1990s using underground water.

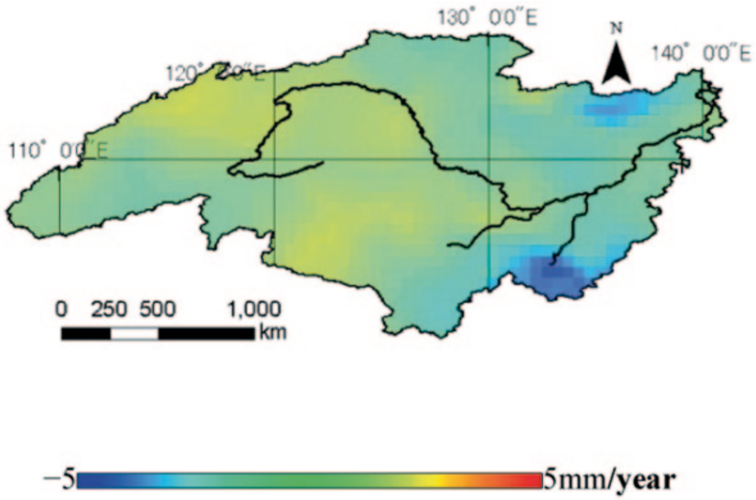


Fig. 2.27 Secular trend of mean precipitation in May using CRU TS from 1982 to 2000

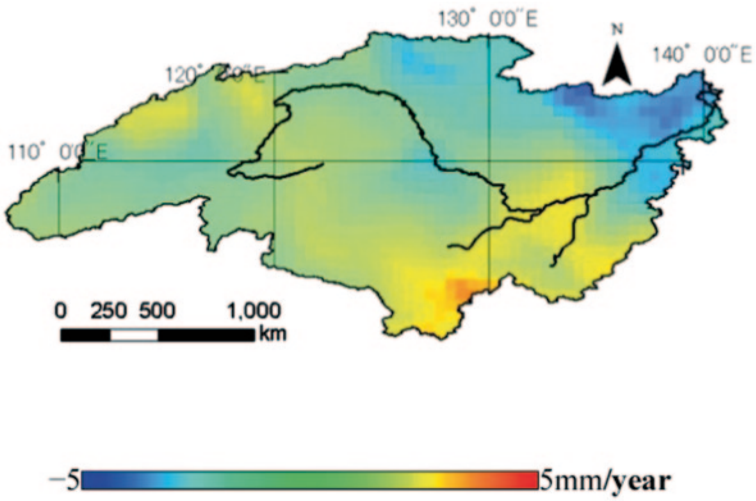


Fig. 2.28 Secular trend of mean precipitation in June using CRU TS from 1982 to 2000

The total cultivated acreage and paddy fields increased from 1978 to 2000, and upland plowed fields decreased in area with irrigation and drainage channels. During our field investigation, the floodplain was generally used for paddy fields after land reclamation project with drainage and irrigation channels, whereas soybeans and corn were mainly grown on hillside and fluvial terraces. In the Harbin urban expansion and Sanjiang Plain areas, paddy field irrigation was steady at the beginning

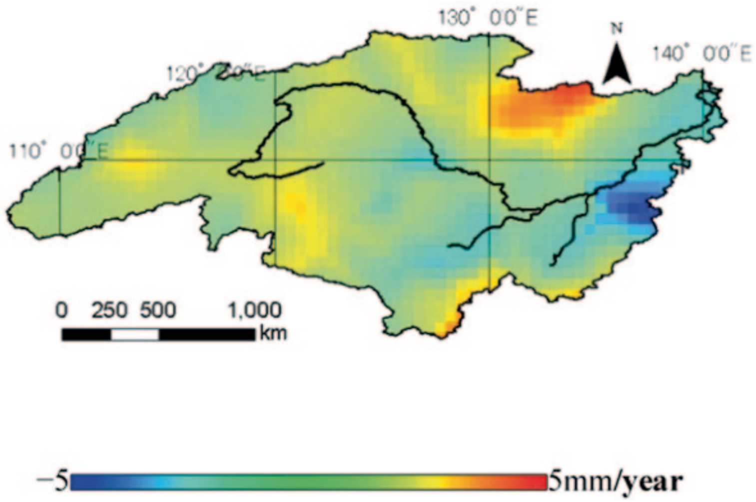


Fig. 2.29 Secular trend of mean precipitation in July using CRU TS from 1982 to 2000

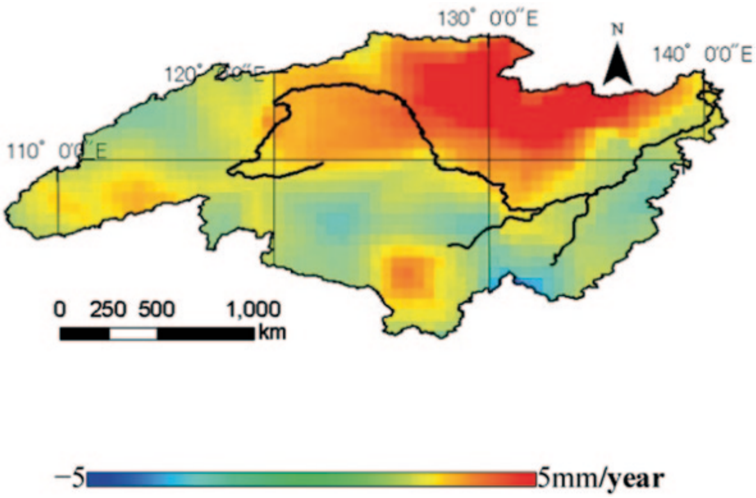


Fig. 2.30 Secular trend of mean precipitation in August using CRU TS from 1982 to 2000

of the 1990s. Irrigated areas have increased since 1990 on the Sanjiang Plain. The increase of irrigated areas in the late 1990s is believed to have come at the expense of the few remaining natural wetlands on that plain. The wetlands have been lost and the biodiversity of the wetlands and surroundings has been deteriorated surface soil.

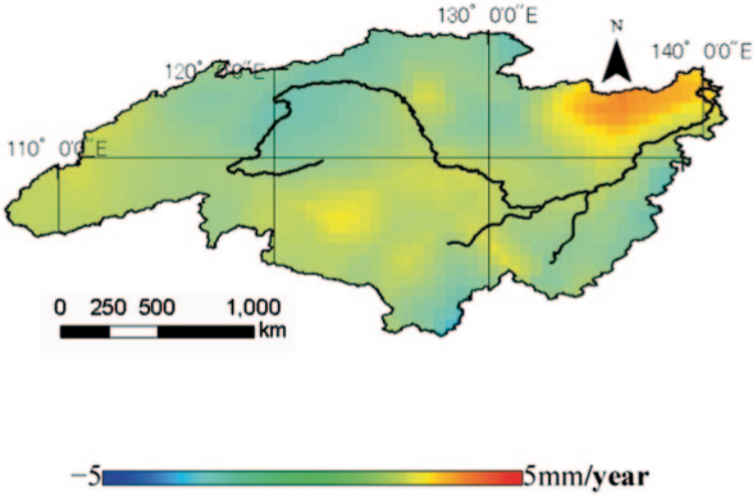


Fig. 2.31 Secular trend of mean precipitation in September using CRU TS from 1982 to 2000

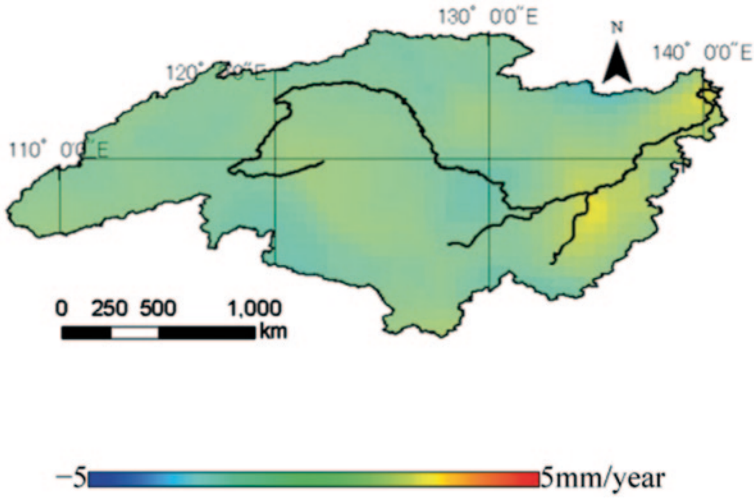


Fig. 2.32 Secular trend of mean precipitation in October using CRU TS from 1982 to 2000

The middle reach of the Amur River is known as the Sanjiang Plain and Songnen Plain, and here is a broad floodplain with peaty lands and fluvial terraces with former swamps. The flood prone area is occupied by 36% of this Plain, and Chinese Central Government Land Reclamation Projects of swamps started since 1947 for food security in China. The Sanjiang Plain is one of the national food storage bases and has been developed for state farms with irrigation and drainage systems

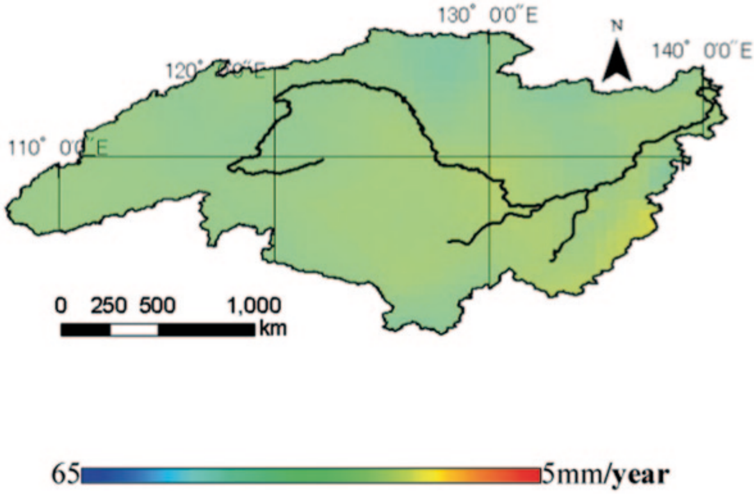


Fig. 2.33 Secular trend of mean precipitation in November using CRU TS from 1982 to 2000

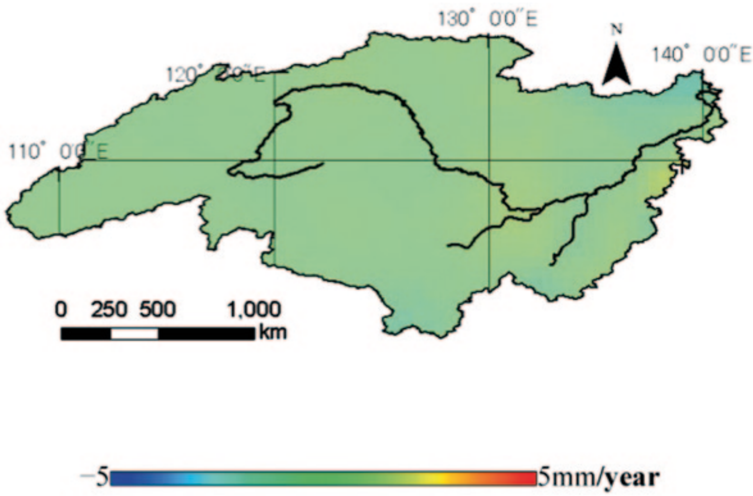


Fig. 2.34 Secular trend of mean precipitation in December using CRU TS from 1982 to 2000

after 1980. The land cover of this plain and surroundings are remarkable changed and fluvial terraces are targeted to paddy fields converted from upland crop field (Sakashita and Park 2010; Park and Sakashita 2010). $NDVI_{max}$ increased in a floodplain that has seen active development of paddy fields. Both north and south parts of the Songhua River Basin, $NDVI_{max}$ was under 0.01 and TRJ about −3.0. These land cover changes on the floodplain and fluvial terraces between the Songhua and

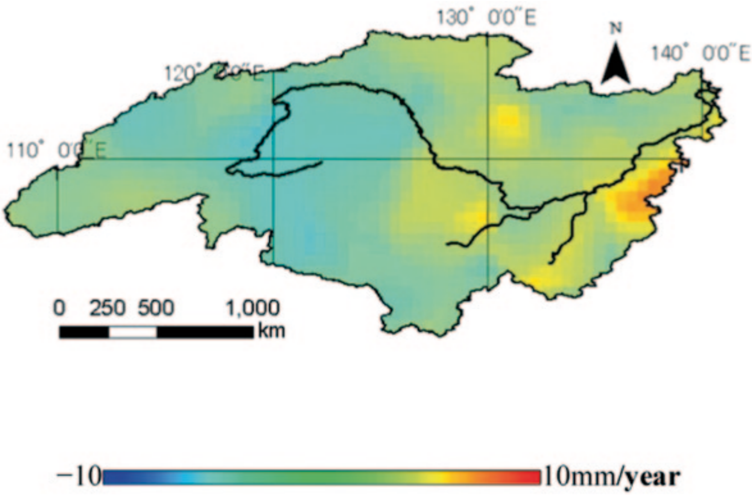


Fig. 2.35 Secular trend of mean precipitation using CRU TS from 1961 to 1990

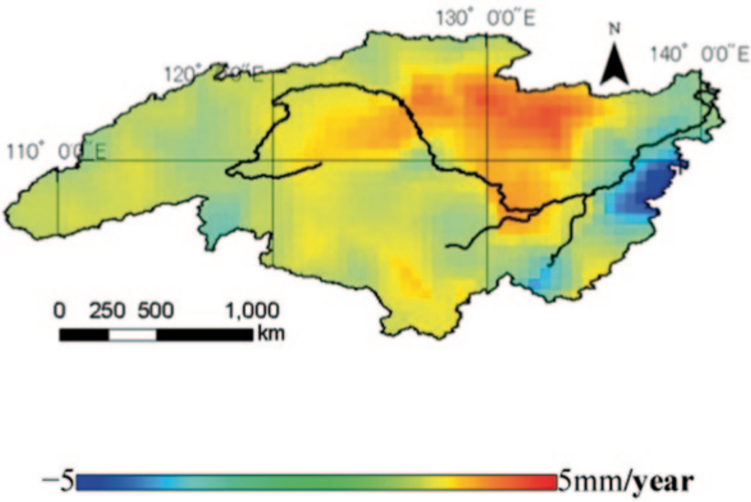


Fig. 2.36 Secular trend of mean precipitation using CRU TS from 1991 to 2000

Amur Rivers do not correspond to any relief structure. Advancing irrigation system in these plains with underground water pumping, the underground water resources have become depletion in the core farms. As biomass increases and conditions for vegetation growth improve, transpiration becomes more vigorous and Ts decreases. The ground level is changed by land transformation with ditch systems in channels reducing Ts (Kondoh et al. 2002). Ts is also same trend of CUR TS data in

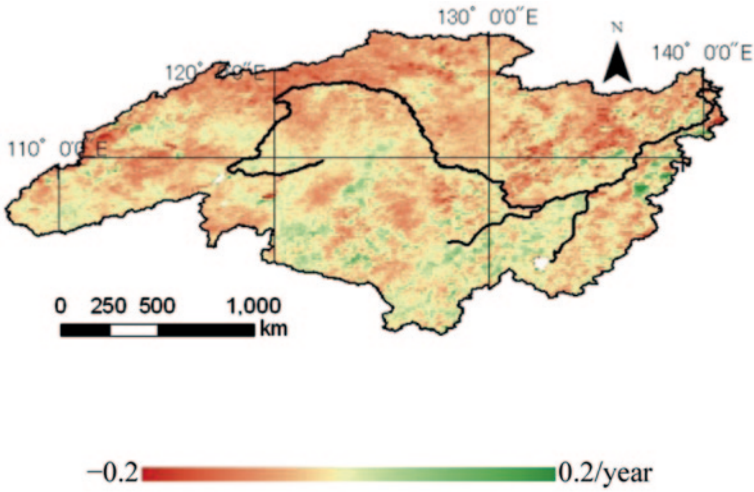


Fig. 2.37 The distribution map of ΣNDVI secular variation in last 20 years

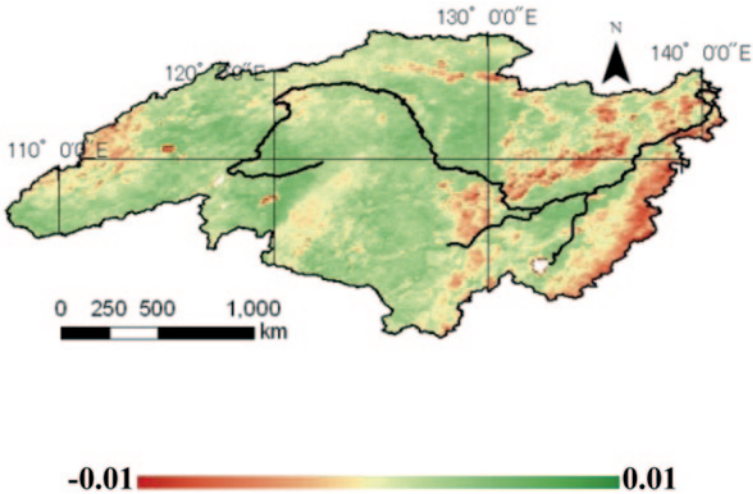


Fig. 2.38 The distribution map of $NDVI_{std}$secular variation in last 20 years

this area. TRJ is also reduced by these factors. The periodic trends of land cover change can be interpreted as the reflect growth of agricultural activity after lost natural vegetation. The natural wetlands of the type found on this floodplain are the most important original landscape of land form with vegetation. Honghe Lake and the swamps where is confluence between the Amur and Ussury rivers are both in Sanjiang Plain are designated to the Ramsar Convention Swamps because there

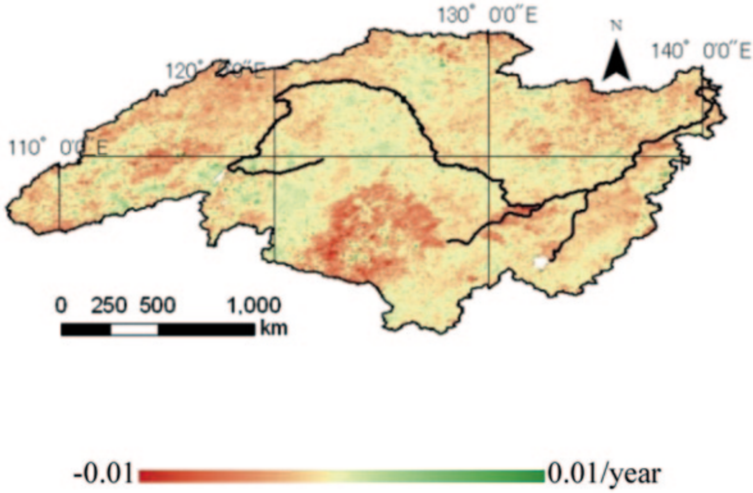


Fig. 2.39 The distribution map of NDVI $_{max}$secular variation in Last 20 years

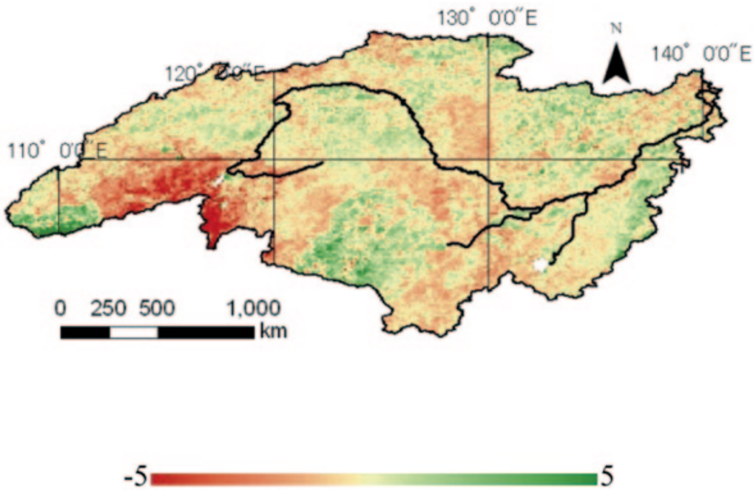


Fig. 2.40 The distribution map of TRJ secular variation in last 20 years

are nests of some kinds of migratory cranes wild gooses. These Ramsar Convention Swamps are essential places for environmental conservation and biological diversity in Northeast China. The result of analysis of CRU TS data demonstrates the heat budget existence.

The Harbin and Jamusi urban expansion areas are corresponding to the Songnen Plain and Sanjiang Plain. An increase in $NDVI_{max}$ was remarkable on the developed

Table 2.1 Transition of sown area to commercial crops in Heilongjiang province (Unit: 10,000 ha). (Source: China Map Office 2004)

Year	Rice	Wheat	Corn	Soybean
1978	21.41	174.72	189.04	152.49
1979	20.63	185.93	196.08	166.51
1980	21.04	210.52	188.4	163.01
1981	22.41	219.03	157.7	179.97
1982	23.92	190.43	136.34	213.55
1983	24.55	209.63	164.16	169.25
1984	27.75	198.02	192.01	179.54
1985	38.97	203.79	157.66	216.74
1986	50.69	196.91	168.9	219.67
1987	58.06	158.69	197.55	239.95
1988	55.29	123.87	182.75	242.89
1989	60.41	168.18	190.35	226.38
1990	67.35	178.11	216.85	207.87
1991	74.69	173.68	223.01	209.42
1992	77.84	161.46	216.59	216.02
1993	73.55	133.65	177.68	297.92
1994	74.82	119.47	196.41	279.57
1995	83.5	111.6	241.1	251.3
1996	110.9	123.7	266.6	216.1
1997	139.7	107.4	254.5	239.4
1998	156.3	95.9	248.6	246
1999	161.5	95.3	265.2	215.3
2000	160.6	59	180.1	286.8

floodplain, fluvial terraces and on hill slopes. $NDVI_{max}$ was 0.005 in the hills north of Harbin urban expansion. Hill slopes west and southwest of Harbin urban area where are mid arid area with saline soil had an $NDVI_{max}$ of 0.006. ΣNDVI and TRJ showed obvious changes on the fluvial terraces and gentle slopes of hillsides, where ΣNDVI was 0.1 and TRJ was less than −1. The Saline-Alkaline soil is widely spreading surrounds of western Harbin and this is bringing to land degradation (Haruyama 2005). In an area extending 200 km north of Harbin city that has undergone increased urban land use at the expense of paddy fields since the 1980s (Motoki 2001), ΣNDVI was 0.1. These trends are similar to Songnen Plain, and can also be interpreted as indicative of land-cover change in response to irrigated agricultural development with drainage systems. After 1990s, the over pumping of the underground water is a trigger of saline soil expansion, subsidence of surface and land degradation. ΣNDVI increases in more elevated areas are consistent with increased afforestation.

The other peripheral or marginal area of the Amur River basin is the difference land cover signals in each. The Northern part of the Amur River Basin is widely covered by coniferous forest (Olson et al. 1983) and boreal forest (Ganzey 2005). The area of ΣNDVI = 0.05 or more (Fig. 2.37) coincided with an old low relief mountainous district and rugged hills. $NDVI_{std}$ (Fig. 2.39) was also high (1.5 or more) in the area of elevated ΣNDVI. No notable change in $NDVI_{max}$ or TRJ was

Table 2.2 Transition in production of commercial crops in Heilongjiang province (Unit: 10,000 t). (Source: China Map Office 2004)

Year	Rice	Wheat	Corn	Soybean
1978	71.5	254.5	602	208
1979	71.7	333.2	581	185.5
1980	79.6	394.6	520	220.5
1981	55.7	314.1	455	188.3
1982	70.9	268.2	352.6	245.5
1983	91.5	451	463.5	238.5
1984	124	382.5	642	290.5
1985	162.9	376.8	386.8	313.7
1986	220.8	355.9	632	378
1987	225.7	299.8	646.1	383.5
1988	243.5	250.4	700.6	384.4
1989	231.7	367.3	615.2	291.8
1990	314.4	474.8	1008.3	325.8
1991	316.2	381.1	1007.5	309.8
1992	376.6	424.8	1042.8	349.1
1993	388.3	340	956.6	491.5
1994	410.4	275.3	1146.4	513.6
1995	469.9	293.4	1219.1	438.8
1996	636.6	329.5	1445	413.5
1997	860.9	328.4	1165.9	576.2
1998	925.8	285.2	1199.7	444.6
1999	944.3	284.2	1228.4	446.6
2000	1042.2	95.8	790.8	450.1

seen across the region (Figs. 2.39 and 2.40). Myneni (1997) found increased vegetation activity related with LAI in this area and discussed its relationship to warming in northern Eurasia during 1982–1990. Our climate change analysis of the CRU TS data confirmed that mean temperature in February increased between 1982 and 2000, which appears to be reflected by an increase in ΣNDVI value. The vegetation growth period was extended and snow melted earlier in spring because the temperature rose earlier in the winter. Moreover, $NDVI_{std}$ increased because the difference in ΣNDVI within each year grew larger. The Northern Area of the Amur Basin can be interpreted as a region readily influenced by yearly changes in meteorological conditions or climate change and land cover change is specific condition (Makhinova 2003).

The Eastern Area of the Amur River Basin contains wide dark coniferous forests. Dauirian larch forest with Korean pine and broadleaf forest are common in the Ussury River Basin. An area where $NDVI_{std}$ was greater than 1.5 and ΣNDVI was 0.05 extends from southwest to northeast along the basin boundary. There was no marked change of $NDVI_{max}$ or TRJ. However, an area where $\Sigma NDVI = -0.2$ is meaning biomass diminution and less biomass is extended from Khabarovsk Krai to the more eastern place. There were large-scale forest fires in Khabarovsk Krai between 1998 and 1999, and the Far Eastern forest is suffered fire damage and bared land increased after 1998. The creep and soil erosion after forest fire was occurred

Table 2.3 Transition of total cultivated area, rice fields, and upland fields in Heilongjiang province (Unit: 10,000 ha). (Source: China Map Office 2004)

Year	Total cultivated area	Rice field	Upland field
1978	845.8	22.9	822.9
1979	866.3	22	844.3
1980	872.6	21.5	851.1
1981	875.5	22.9	852.6
1982	871.9	24.5	847.4
1983	875.1	25.5	849.6
1984	890.9	28.7	862.2
1985	893.1	39.4	853.7
1986	905	51.1	853.9
1987	885.9	57.8	828.1
1988	883.4	56.4	827
1989	882.6	60.9	821.7
1990	883.1	68.1	815
1991	884.7	75.6	809.1
1992	890	79.1	810.9
1993	890.8	78.1	812.7
1994	890.9	77	813.9
1995	899.5	86.9	812.6
1996	917.5	114.1	803.4
1997	922.4	139.9	782.5
1998	924	156.3	767.7
1999	926	161.5	765.1
2000	961.7	164.7	797

and land degradation advanced to lower plain from mountain area. We therefore infer that the decrease of ΣNDVI in this area and corresponding decrease in biomass resulted from forest fires. It may also be that NDVI values were smaller because smoke greatly obscured the ground. The land cover change signals are related with land degradation in this area. CRU TS is showing the temperature changes in this period.

The Western Dry Area of the Amur River Basin contains wide grass land on the Cretaceous plateaus and rugged hills. The area has a steppe and is mainly covered by pasture in Mongolia territory. The grass land with swamps was extended in this area in 1930s Land Use Map and the vegetation has not much changed in 2000. The entire area had TRJ = 3, but ΣNDVI, $NDVI_{max}$, and $NDVI_{std}$ showed no marked changes. The increase of TRJ must have come from an increase in Ts. Pasture has a period of bare ground between snowmelt and foliation and, in our interpretation of ΣNDVI, $NDVI_{max}$, and $NDVI_{std}$ data as well as the vegetation in the area, that period lengthened from 1982 to 2000. Moreover, Ts increased because snowmelt occurred increasingly early, as did TRJ according to CUR TS data analysis also. An increase in the bare ground period does not have a simple relationship to an increase of pasture vegetation biomass, because it is influenced by each climate factor that are calculated using CUR TS data and in this area soil water content are few. Kondoh et al. (2002) separated global vegetation zones into water-dependent and energy-dependent types, and they placed this area in a transition belt between them. The influence of twenty-first-century climate change and anticipated human activity makes it likely that the boundary of this eco-zone will be highly vulnerable to change.

2.6 Conclusion

Comparative analysis between CRU TS and NDVI, the remarkable land cover change signals demonstrates land degradation. After deriving spatial trends of land cover in the Amur River Basin in the last 20 years using remote sensing data, we examined land-cover change in the Amur River Basin by combining and interpreting four indices calculated from each NDVI factor. The North and East areas are interpreted as regions influenced by both yearly variations of meteorological conditions and global climate change. We conclude that changes in the NDVI trend analysis and CRU TS data analysis resulted from a rise in winter temperature and earlier dates of snowmelt. Anthropogenic land-cover changes are especially notable in the grain production region of Heilongjiang Province, such as Sanjiang Plain, Songnen Plain and Harbin urban expansion areas. We confirmed that the secular trend of each parameter in these regions was associated with increases in irrigated land for rice farming, and the land degradation in the main land cover change area. These land cover changes connected with flooding with land slide on the hill slopes. Western Dry Area is probably a complex response to variations of temperature, precipitation, and soil water content. This area appears highly susceptible to the effects of future climate change and human activity. Therefore, monitoring should continue and more detailed research should be done for this area towards to conservation of nature as the Ramsar convention lakes with biodiversity in near future. In particular, the conversion of wetland to farmland may be altering the ecosystem of the Amur River Basin. Future research should make use of high-resolution satellite imagery to focus on spatial change in wetland areas and on changes in the flux of material in the Amur Basin related to wetland reclamation. The results of analysis CUR TS are indicated with remarkable land use change with climate change trends.

Acknowledgements We thank Assistant Prof. Kotaro Yamagata, Joetsu University of Education, and Dr. Dexuan Wang, Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences for their help in obtaining ground-truth data. We also thank Assistant Prof. Dr. Sergey Ganzey, Russian Academy of Sciences, Pacific Geography Institute for help with field research in the Russian territory.

References

Bonan GB (1993) Importance of leaf area index and forest type when estimating photosynthesis in boreal forests. Remote Sens Environ 43:303–314

Box EO, Holben BN, Kalb V (1989) Accuracy of the AVHRR vegetation index as a predictor of biomass, primary productivity and net CO_2 flux. Vegetation 80:71–89
China Map Office (2004) Atlas of China. China Map Publishers, Beijing (in Chinese)
China Statistics Office (2001) Statistics of Heilongjiang province. China Statistics Publishers, Beijing
Deng X, Liu J, Liu M, Xu X, Zhan J, Zhao T (2001) Land use change and dynamics for the ecotone between agriculture and Pasturing in Northeast China 1990–2000. China-Jpn Comp Study Land Use/Cover Changes I:61–84
Doi H, Zhang S (2001) Land use change in the built up area of Changcun city, China. China-Jpn Comp Study Land Use/Cover Changes I:39–46
Ganzey SS (2005) Transboundary Geo-systems in the South of the Russian Far East and in Northeast China. Dalnauk, Vladivostok, pp 148–159
Goward, SN, Tucker CJ, Dye DG (1985) North American vegetation patterns observed with the NOAA-7 advanced very high resolution radiometer. Vegetation 64:3–14
Haruyama S (2005) Land use and land cover of river Basin-Amur-geographical view and human impact. Rep Amur-Okhotsk Proj 3:117–124
Haruyama S, Kondoh A, Murooka M, Masuda Y (2010) Land use and land cover change study. Rep Amur-Okhotsk Proj 6:71–74
Haruyama S, Murooka M, Kuwahara Y (2013) The Amur river discharge with landform. In: Proceedings of the 3rd international meeting of Amur-Okhotsk consortium 2013, pp 33–36
Haruyama S, Masuda Y, Kondoh A (2014) Long term land cover change in the Amur river basin. In: Ademola KB, He QH (eds) Vulnerability of land systems in Asia. Wiley, New York
Himiyama Y (2001) Land use change in northeast China—GIS database and evaluation for sustainable development. LU/GEC land use for global environmental conservation project report, vol VII, pp 83–98 (in Japanese)
Kondoh A (2004) Analysis of vegetation and land cover change using global remote sensing. Jpn Soc Hydrol Water Resour 17(5):459–467 (in Japanese)
Kondoh A, Tateishi K, Park R (2002) Relating vegetation activity to climatic variation and atmospheric CO_2 content. Jpn Soc Hydrol Water Resour 15(2):128–130 (in Japanese)
Kondoh A, Kaihotsu I, Hitata A, Dorgorsuren (2005) Inter annual variation of phenology and biomass in Mongolian herbaceous vegetation. J Arid Land Stud 14(4):209–218 (in Japanese)
Lin M, Hasegawa K (2005) The problems on the large-scale management of rice production in Heilongjiang province: a case study on G-village in Fujin city. Bull Dep Agric 32:61–78 (in Japanese)
Liu J, Deng X, Liu M, Zhang S (2001) Spatial pattern of land use change and analyses of driving forces in northeast China during the past ten years. China-Jpn Comp Study Land Use/Cover Changes I:11–22
Luo H (2001) Land use change of the Jilin province in the past 15 years. China-Jpn Comp Study Land Use/Cover Changes I:23–30
Makhinov AN (2010) Natural factors of Amur runoff and sediment deposit formation. Rep Amur-Okhotsk Proj 6:117–122
Makhinova A (2003) Smoke from forest fires and innocent hostages to experiments with nature. Sib Agreem Interreg Assoc (a quarterly political information and analytical illustrated magazine) 2–12:47–52
Motoki Y (2001) Agricultural land use change of north east China—a view of role of rice production. LU/GEC land use for global environmental conservation project report, vol VII, pp 83–98 (in Japanese)
Murooka M, Haruyama S, Masuda Y (2007a) Land cover change detected by satellite data in the agricultural development area of the Sanjiang plain, China. J Rural Plan Assoc 26:197–202
Murooka M, Haruyama S, Masuda Y, Yamagata K, Kondoh A (2007b) Analysis of land cover on the Sanjiang plain, china using JERS-A/SAR data. Rep Amur-Okhotsk Proj 4:161–168
Myneni RB, Hall FG, Sellers PJ, Marchak AL (1995) The interpretation of spectral vegetation indexes. IEEE Trans Geosci Remote Sens 33:481–486

Myneni RB, Keeling CD, Tucker CJ, Asrar G, Nemani RR (1997) Increased plant growth in the northern high latitudes from 1981 to 1991. Nature 386:698–702
Nemani R, Running S (1997) Land cover characterization using multi temporal red, near-IR and thermal-IR data from NOAA/AVHRR. Ecol Appl 7(1):79–90
Nemani R, Keeling CD, Hashimoto H, Jolly WM, Piper SC, Tucker CJ, Myneni RB, Running SW (2003) Climate-driven increases in global terrestrial net primary production from 1982 to 1999. Science 300:1560–1563
Olson JS, Watts JA, Allison LJ (1983) Carbon in live vegetation of major world ecosystems. Report ORNL-5862, Oak Ridge National Laboratory, Tennessee
Park K, Sakashita A (2010) Characteristic of agricultural development on Sanjiang Plain, China—from a macro aspect of the paddy fields development of state farm. Rep Amur-Okhotsk Proj 6:283–290
Price CJ (1984) Land surface temperature measurement from the split window channels of the NOAA 7 advanced very high resolution radiometer. J Geophys Res 89:7231–7237
Sakashita A, Park H (2010) Development of water facilities, farm land and land use change in Sanjiang plain. Rep Amur-Okhotsk Proj 4:123–128
Sannier CAD, Taylor JC, du Plessis W, Campbell K (1998) Real-time vegetation monitoring with NOAA/AVHRR in southern Africa for wildlife management and food security assessment. Int J Remote Sens 19(4):621–639
Shiraiwa T (2005) The Amur Okhotsk project. Rep Amur-Okhotsk Proj 3:1–2
Spanner MA, Pierce LL, Running SW, Peterson DL (1990) Seasonal AVHRR data of temperature coniferous forests: relationship with leaf area index. Remote Sens Environ 33:97–112
Tachibana Y (2003) Discharge trend and its mechanism of the Amur River. Rep Amur-Okhotsk Proj 1:26–30
Tucker CJ (1979) Red and photographic infrared linear combinations for monitoring vegetation. Remote Sens Environ 8:127–150
Wang Q, Adiku S, Tenhunen J, Granier A (2005) On the relationship of NDVI with leaf area index in a deciduous forest site. Remote Sens Environ 94:244–255
Yamagata K, Haruyama S, Masuda Y, Murooka M (2007) Geomorphological research in Sanjiang plain 2006. Rep Amur-Okhotsk Proj 4:169–172
Zhang Y (2000) Deforest transition: theory and evidence in China. In: Palo M, Vanhanen H (eds) World forests from deforestation to transition? Kluwer Academic, Dordrecht, pp 41–65

Chapter 3
Wetland and Flooding in the Amur River Basin

Mizue Murooka and Shigeko Haruyama

Abstract The Sanjiang Plain has been cultivated by the Chinese government since the 1950s. Change in its land cover has caused serious flooding. By contrast, the Kiya River Basin in Russia, on the opposite side of the Sanjiang Plain, has not experienced a change in land cover. In this study, a geomorphological map was made, and land cover change on the Sanjiang Plain is clarified using Shuttle Radar Topography Mission and Japanese Earth Resources Satellite 1 Synthetic Aperture Radar data. The wetland condition for the Kiya River Basin is also examined. Finally, human impacts on the Sanjiang Plain are analyzed. Land in the study area was significantly cultivated; one-third of the alluvial plain was cultivated from 1992 to 1996. The Kiya River Basin is always submerged and rarely suffers major floods. The history of land cover change corresponds to the time series of annual minimum discharge. The water holding capacity has been lost and floods occur more frequently because the wetland has disappeared.

Keywords Sanjiang plain • Land cover change • Wetland

3.1 Introduction

The Sanjiang Plain historically had the largest wetland in northeast China. However, beginning in the 1980s when agricultural development was emphasized in the Chinese economic growth plan, remaining wetlands were drastically reclaimed up until the 2000s. At present, continuous conservation processes of the natural environment in China and Russia differ. The human impact on large international rivers had a wide-reaching effect. There were once many wetlands on the Sanjiang

M. Murooka (✉)
Abashiri Fisheries Research Institute, 1-1-1 Masuura,
099-3119 Abashiri, Hokkaido, Japan
e-mail: murooka-mizue@hro.or.jp

S. Haruyama
Graduate School of Bioresources, Mie University,
514-8507 Mie, Japan
e-mail: haruyama@bio.mie-u.ac.jp

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_3

Plain, but since the 1950s, much wetland area has been reclaimed by the Chinese government. Beginning in the 1980s, the cultivated area has increased because of the introduction of Japanese agricultural technology (Ganzey 2005).

The wetlands are distributed across various landforms, and reclamation projects of varying intensity affect the environment around the wetlands in different ways. In this study, a landform map based on ground truth is prepared in advance. The distribution and characteristics of wetlands on selected landforms are determined by satellite images, and croplands are sorted by two types of satellite data. The landforms on which the wetlands were reclaimed are examined. Human impact drastically affects the natural environment. Ogura and Yamamoto (2005) described the following human impacts on rivers: reservoirs, water diversion, drainage, embankments, vegetation change along the river, watershed development, land use change, groundwater use, exotic species invasion, rapid change of the global environment in the last decade, and chemical discharge such as fertilizers, pesticides, and others into the stream. These factors ultimately affect river discharge, sediment amount, and water quality, e.g., water temperature, nutrients, and dissolved substances.

3.2 Natural Environment of Sanjiang Plain

Maps of the Amur River and Sanjiang Plain are shown in Fig. 3.1 and the development process of the Amur River is shown in Table 3.1 Shiraiwa (2011) described land use changes of the Amur River Basin during the Qing Dynasty, which was an important period for reclamation projects involving the middle reaches of the Amur River. Afterward, the Manchuria Immigrant Period of 1930–1945 and the Second World War were important epochs of the Chinese government for promoting expansion of reclaimed land by the People's Liberation Army. The wetlands have been reclaimed since the 1980s in China. In Russia, forests of the northern Amur River area were logged according to the Treaty of Aigun in 1958, and those in the eastern area were logged as a result of the Treaty of Beijing in 1980. Forest conditions worsened after the breakup of the Soviet Union, and there was a population density much smaller than that in China. Ganzey et al. (2010) prepared a land use map of the Amur Basin in the 1930s and 2000s, using topographic maps published in different periods. Percentages of land use in the categories of forest, grasslands, crop fields, paddy fields, and wetlands were respectively 60, 17, 7, 0, and 13 % in 1930 and 59.5, 12.2, 17, 1, and 7 % in 2000. Sixty percent of the area was forest in Russia during the 2000s and 46 % in China. The main land use in Mongolia came from extensive natural grasslands. Thirty-three percent of all land use in China was from reclaimed land, whereas this proportion in Russia was 5 %.

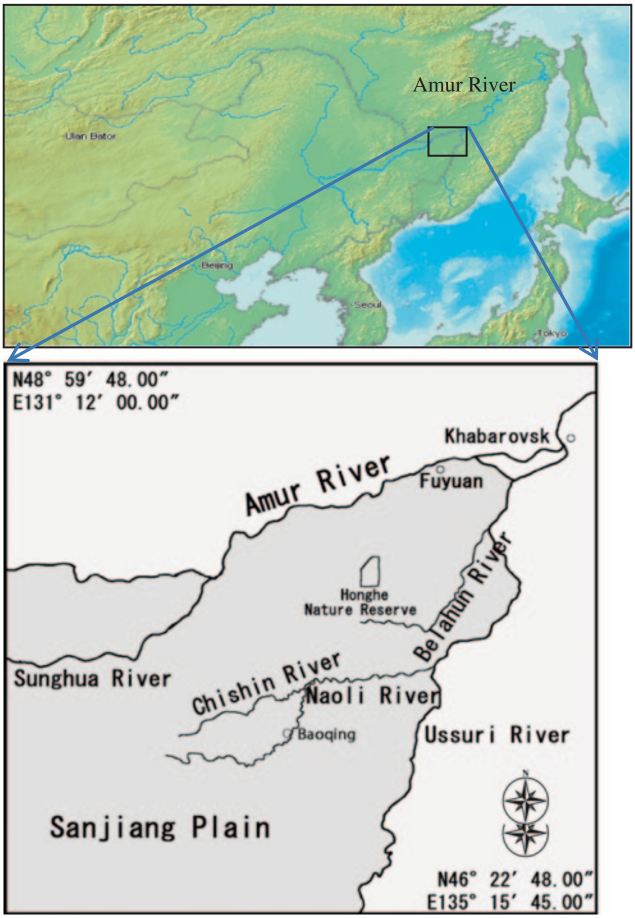


Fig. 3.1 Sanjiang plain map

Table 3.1 Chronology of Amur River development

	Human impact	
Year	Russia	China
1850s		First reclamation by Qing
1930–1945		Reclamation by Japanese
1945–		Extensive reclamation by Chinese Government
1860–	Logging	
1970s	Zeya reservoir	
1980–2000		Reclamation by StateFarm
2002		Longtouqiao reservoir in Baoqing

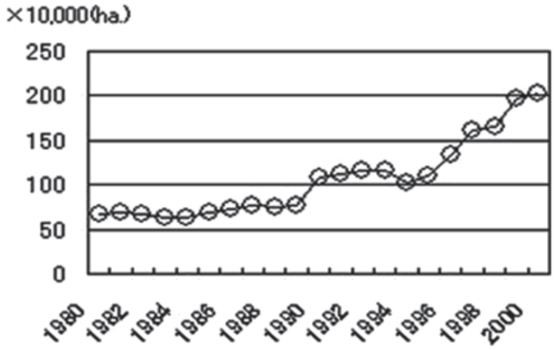


Fig. 3.2 Paddy with irrigation in Heilongjiang Province. (After Masuda et al. 2006)

3.3 Geographic Setting of Sanjiang Plain

The Sanjiang Plain is the alluvial plain with three rivers, the Amur, Sunghua and Ussuri Rivers. Landform relief is uniform at 1/10,000–1/20,000, and sediment of the fluvial terraces and upper floodplain is silt clay with 5–15 m thickness. The peat layer is usually 30 m thick on the Sanjiang Plain (Umitsu 1980). This layer was formed by intensive subsidence from tectonic movements during the Quaternary, which also influenced geomorphologic evolution during the Holocene. Thus, the fluvial geomorphology of the plain is key to understanding local fluvial processes. The wetlands were cultivated since the 1980s, and agricultural land has expanded rapidly because of the introduction of Japanese agricultural technology (Ganzey 2005). Wetland remains only on the northeast Sanjiang Plain, where the Chinese government began wetland conservation projects such as the Honghe National Nature Reserve. Masuda et al. (2006) analyzed recent land cover change, and their study area showed a remarkable cultivated area emerging over 20 years (Fig. 3.2).

3.4 Landform and Land Cover Change on Sanjiang Plain

3.4.1 Geomorphological Land Classification Mapping

Figures 3.3 and 3.4 show a cross-sectional map and elevation map from Shuttle Radar Topography Mission (SRTM) DEM data, and Fig. 3.5 and Table 3.2 show the Japanese Earth Resources Satellite 1/Synthetic Aperture Radar (JERS-1/SAR) data used. SRTM includes altitude data from C-band and X-band SAR mounted on the Space Shuttle for 11 days in February 2000. The SRTM data covers 80% of the continent, except polar areas. There are two types of these data. SRTM-3 is on a 3 arc s (90 m) mesh for the entire world (except polar areas), and SRTM-1 is on a 1 arc s (30 m) mesh. JERS-1 was launched by NASA in 1992 and operated until 1998. The JERS-1 SAR used L band, which was suitable for measuring soil water content, and digital data values are called backscattering coefficients.

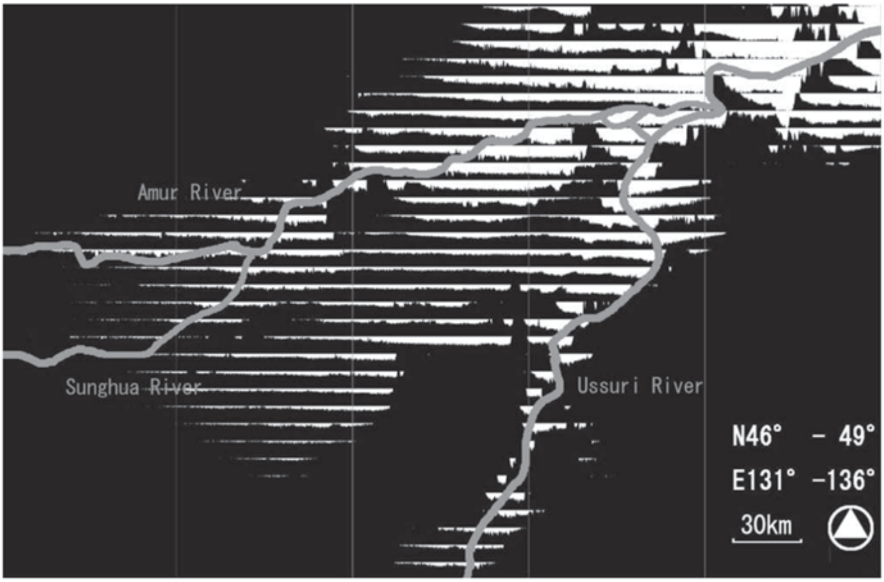


Fig. 3.3 Cross section of Sanjiang plain

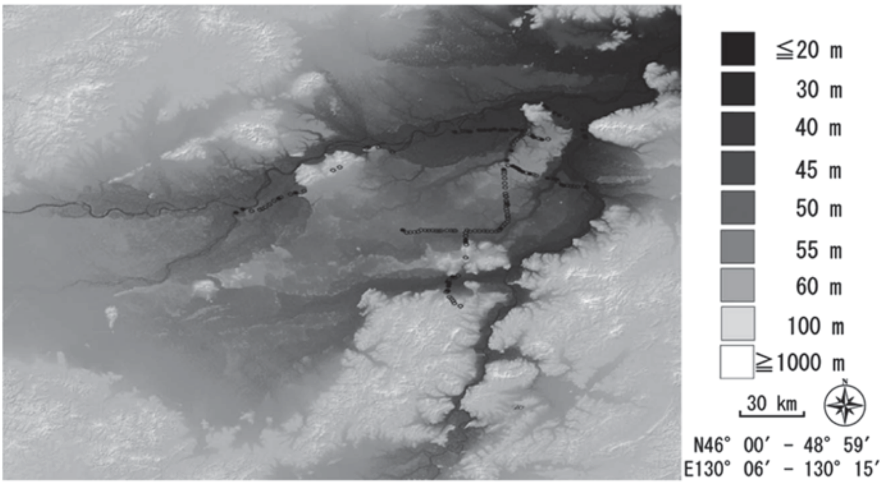


Fig. 3.4 Elevation map of Sanjing plain (*white circles* indicate farms and *black circles* indicate wetlands)

When soil water content is high, a pixel appears blackish, and water surfaces are black. JERS-1/SAR data had the following characteristics: scan width 75 km, resolution 18 × 18 m, pixel spacing 12.5 m, off-nadir angle 35°, observation frequency 1275 GHz, polarized wave HH, return interval 44 days, and wavelength 23.5 cm.

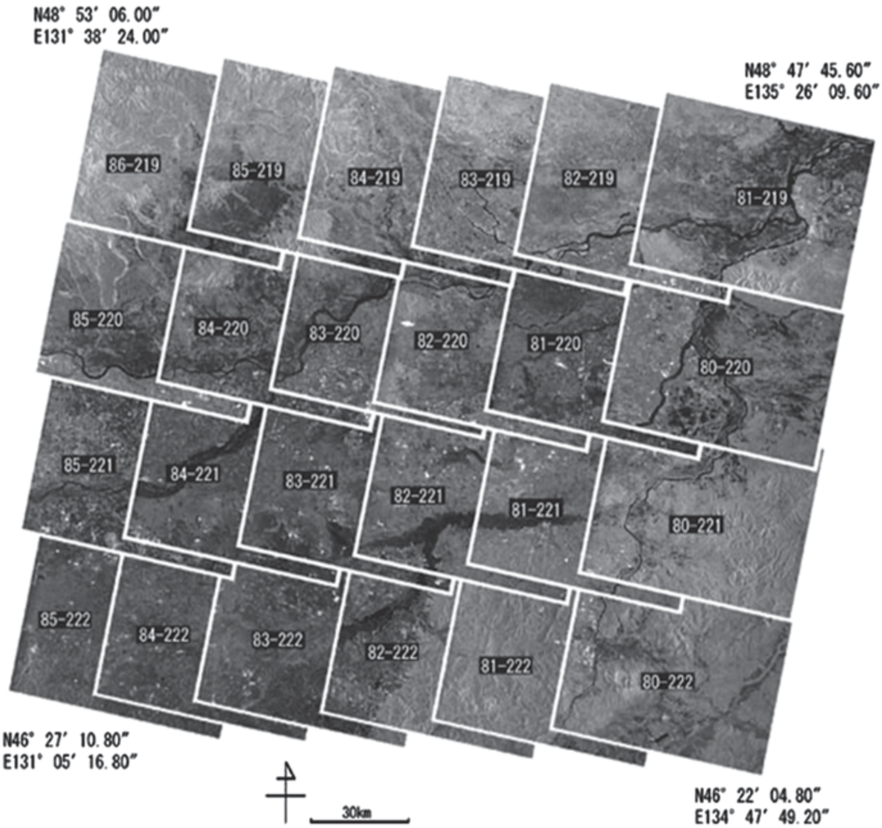


Fig. 3.5 JERS-1/SAR of Sanjiang plain

Table 3.2 JERS-1/SAR data for geomorphologic land classification map

		Path			
		219	220	221	222
Row	80		6-Sep-1996	6-Sep-1996	6-Sep-1996
	81	6-Sep-1996	7-Sep-1996	7-Sep-1996	7-Sep-1996
	82	7-Sep-1996	8-Sep-1996	8-Sep-1996	22-Oct-1996
	83	8-Sep-1996	9-Sep-1996	9-Sep-1996	13-Jun-1996
	84	9-Sep-1996	24-Oct-1996	28-Aug-1997	24-Oct-1996
	85	28-Jul-1996	11-Sep-1996	19-Mar-1996	11-Sep-1996
	86	11-Sep-1996			

In this study, the ground truth was conducted for two weeks during August and September 2005–2009. The authors recorded latitude, longitude, landforms with relative height, and land use at more than 1000 points. Various wetland features were classified based on each landform's units, such as land submerged beneath water and flat land with water surface. Because differences of micro-topography produced a base of vegetation, land cover was depicted and regional characteris-

Table 3.3 Description of landform units on Sanjiang plain

Major division	Landform	Criterion of the landform classificaion
Floodplain	Lower floodplain	The difference of altitude from river was very small (0–8 m). Back scattering coefficient was low (−18.9 to −9.8). Near the river. There were traces of water
	Upper floodplain	The difference of altitude from river was small (7–11 m) and flat. There were many wetlands or former river course
	Natural levee	Developed along the river. Back scattering coefficient was high (−12.3 to −2.4). Altitude was relatively high
Fluvial terrace	Terraces	Other area. By differences from the nearest rivers, it could be classified (Lower terrace 2: 6–14 m, Lower terrace 1: 10–17 m, Middle terrace 2: 17–19 m, Middle terrace 1: 19–23 m, Upper Terrace: 24–26 m)
	Dissected terrace valley	Altitude was lower than the around area. Back scattering coefficient were low (−18.5 to −8.3) but there were little water surface
	Wetland on the terrace	Altitude was lower than the around area. There were the patchy water surface in the dry land
	Former river course	Back scattering coefficient were relatively high (−17.7 to −4.1). The old water courses were clear
Mountains, others	Mountains	Altitude was very high. Back scattering coefficient were high (−14.0 to −1.5) and valleys were clear
	Gentle slope of the Moutains	Neighboring to the mountains. There were the slope of more than 0.05 %. Erosion had apparently occurred
Water surface	Rivers	Back scattering coefficient were very low (−25.3 to −12.5)

tics analyzed. Table 3.3 describes landform units of the Sanjiang Plain and Fig. 3.6 shows a geomorphologic land classification map of the plain. The principle geomorphologic landform units are mountains and hillslopes, fluvial terraces, dissected terraces with valley plains, swamps on each terrace in the upper portion, and floodplains with natural levees and backwater swamps in the lower portion. There are gentle slopes of mountains and hills with recent gullies and uniform fluvial terraces, which are classified into three elevation levels, upper, middle, and lower. We found a dissected terrace valley with small tributaries, a floodplain with natural levee and backwater swamp, and several types of wetland in each landform unit. There are former rivers in the floodplain between the Sunghua and Amur rivers, because of repeated flooding of these rivers. Wetlands persist on the floodplain, dissected terrace valley, parts of terraces, and “Honghe National Nature Reserve”.

3.4.2 Land Cover Change Analysis

Figure 3.7 shows a flowchart for calculating wetland area and agricultural land using a backscattering threshold. GIS data were used to delete misclassified pixels by masking non-paddy area. For ground truth, we obtained positional information in which 50-m distances were plotted on SAR images and normalized

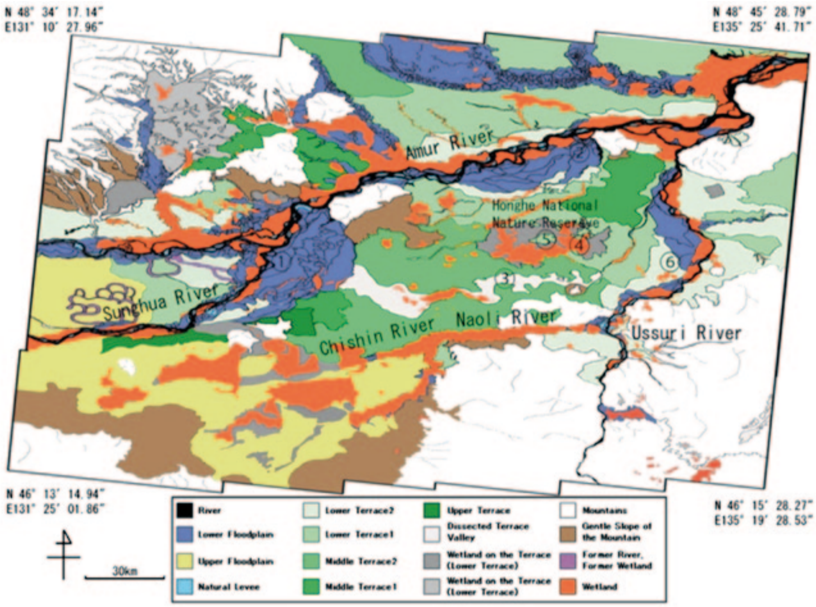


Fig. 3.6 Geomorphologic land classification map of Sanjang plain. *Circles* show wetland areas where field investigations were carried out

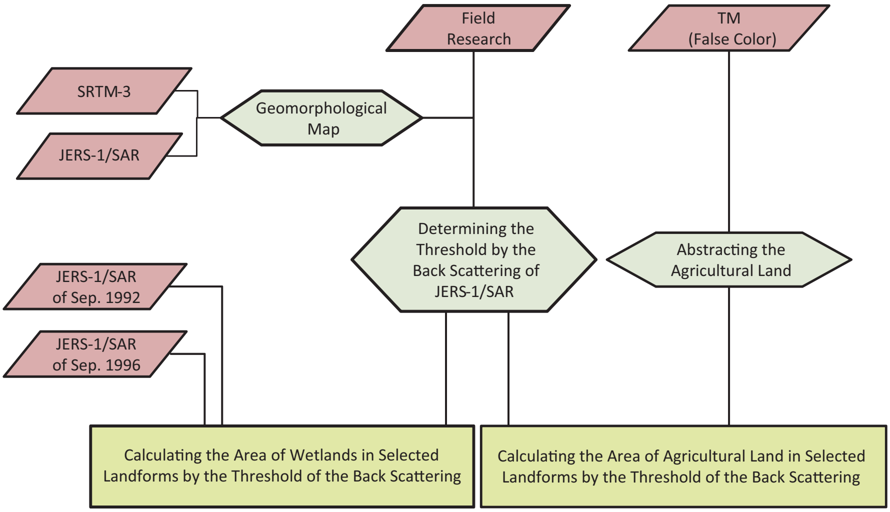


Fig. 3.7 Flowchart for calculating wetland area

radar cross sections (NRCS) at each pixel. The linear transformation was NRCS [dB] $= 10log_{10}(I^2) - CF$, where I is the digital SAR value and CF is the conservation coefficient compared with GPS data of wetlands. Histograms of NRCS for major land covers and wetlands on selected landforms were compared in SAR images

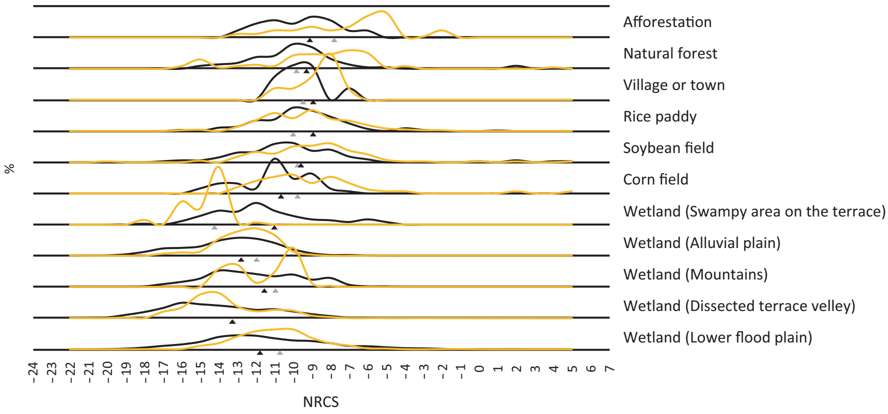


Fig. 3.8 Histograms of NRCS for each land use; "*n*" is number of NRCS pixels. The breadths of the vertical axes are 0–30 %. *Black triangles* show averages for 1996 while *gray triangles* are averages for 1992

of September 1992 and September 1996 (Fig. 3.8). All NRCS averages of non-wetlands were higher than those of wetlands. Averages of non-wetland land covers in 1996 were greater than in 1992, except for afforestation. Average areas of wetlands on each landform in 1996 were less than in 1992, except on the alluvial plain. The authors calculated the area of wetlands using optical data with SAR data and searched for an optimal threshold via empirical cumulative distributions of backscatter. NRCS was characteristically high and lineation of valley borders is clear on satellite images of mountains and hill slopes. There are former river channels with shallow water, and natural levees are on the higher floodplain. Elevation is usually lower than nearby scattered water surfaces within a dry area on the floodplain. For the dissected terrace valley, NRCS is low for water surfaces and wetland is defined by the discrimination ratio between NRCS empirical cumulative distributions of wetland and non-wetland. Thresholds were calculated from 1992 and 1996 SAR images. Dried wetland declining groundwater levels were defined as non-wetland. The Frost filter (proposed by Frost et al. 1982) was applied in the image procedure to remove speckle noise, which was characteristic of SAR data. A geometric correction based on geodetic projection WGS84 was applied via affine transformation. SAR distortion was ignored because of the flatness of the surface. For reclaimed land, false color of the Landsat Thematic Mapper (TM) was used, because irrigated paddy land cover could be classified as reclamation by visual observation of TM data. Non-reclaimed area was masked on wetland images by SAR data. Wetland area in the reclaimed region was then calculated. The area of cropland was calculated by subtracting wetland area in the reclaimed area from reclaimed area of each landform. The study area contained the four regions of Fuyuan, Tonjiang, Fujin, and Raohe. Cultivated area of the four regions was obtained from the Statistical Yearbook of Heilongjiang (1991–1999). Cultivated area change in the 1990s was determined. Verification of conformity between ground truth in 2006 and satellite data from the 1990s was done using TM data from those periods.

Vegetation in each wetland and heights of slightly elevated areas measured by a hand level were recorded on the geomorphologic land classification map. Lineament on SAR imagery is suitable not only for soil water information but also for landform mapmaking (Japan Photogrammetry Associates 1998). Wetland vegetation in each landform unit differs with location; *Calex* spp. and Gramineae spp., which are typical wetland plants, were the principal wetland vegetation on all landforms. In the wetlands of the lower floodplain and dissected terrace valley, there were some submerged areas in which *Typha latifolia* were evident. In wetlands in the swampy area of the terrace, there were alternately dry and wet areas. There were many kinds of plants, such as *Spiraera* sp., *Pteridophyta*, *Umbelliferae* gen. sp., *Artemisia* spp. and small trees such as *Quercus* sp. and *Betula* sp. in the dry area. There was simple vegetation of Gramineae sp. in the wet area. In the wetland on the alluvial plain, there were also alternately dry and wet areas as in the aforementioned wetland, but this wetland was drier. There were some plants which grew in dry places such as *Betula* sp. and *Taraxacum* sp. There were *Calex* spp., Gramineae sp., or *Polygonum hydropiper* in the wet area. In wetlands of the mountains, there were numerous types of plants, such as *Inula* sp., *Crisium* sp., *Polygonum* sp., *Calex* spp. and *Geranium* sp.

3.4.3 Land Cover Change on Sanjiang Plain

Landscapes of the wetlands are shown in Fig. 3.9. Agricultural lands in the 1990s and 2006 from Landsat/TM are shown in Fig. 3.10. It is clear that wetlands on the alluvial plain and swampy area on the terrace remained wetland amongst cropland. Almost all areas of alluvial plain and some areas of swamps on the terrace were cultivated from 1996 to 2006. The area that underwent the greatest change was the alluvial plain. Here, wetland decreased 157,060 ha, and cropland increased 188,800 ha from 1992 to 1996 (Table 3.4). Wetland on the alluvial plain was mainly cultivated. Wetland on the lower floodplain, upper floodplain and mountains decreased by 39,043, 16,123, and 53,046 ha respectively. Cropland increased by 7203, 10,987, and 10,172 ha, respectively. Conversely, the area of wetland on the dissected terrace valley and swamp area on the terrace valley increased by 14,804 and 5464 ha respectively. The area of cropland increased by 11,851 and 15,871 ha, respectively. According to the Statistical Yearbook of Heilongjiang (1991–1999), the sum of cultivated areas in the four regions was 709,764 ha, almost the same as the cropland from satellite data (710,467 ha).

Areas of vegetation comprising each landform were as follows. Alluvial plain: A third of the wetland in 1992 had changed into agricultural land by 1996. Swampy area on the terrace (from field investigation): Almost all wetlands were uncultivated. Dissected terrace valley: Again, almost all wetlands were uncultivated, possibly because of a stream in the lowest area, and conditions were similar to those of the floodplain. Mountains: Once again, almost all wetlands were uncultivated, probably because the steep landform was not suitable for cultivation. Lower floodplain: Almost all wetlands were uncultivated from 1992 to 1996, but there were cultivated areas in 2006. Because elevations are low in the lower floodplains and these are vulnerable to flooding, culti-

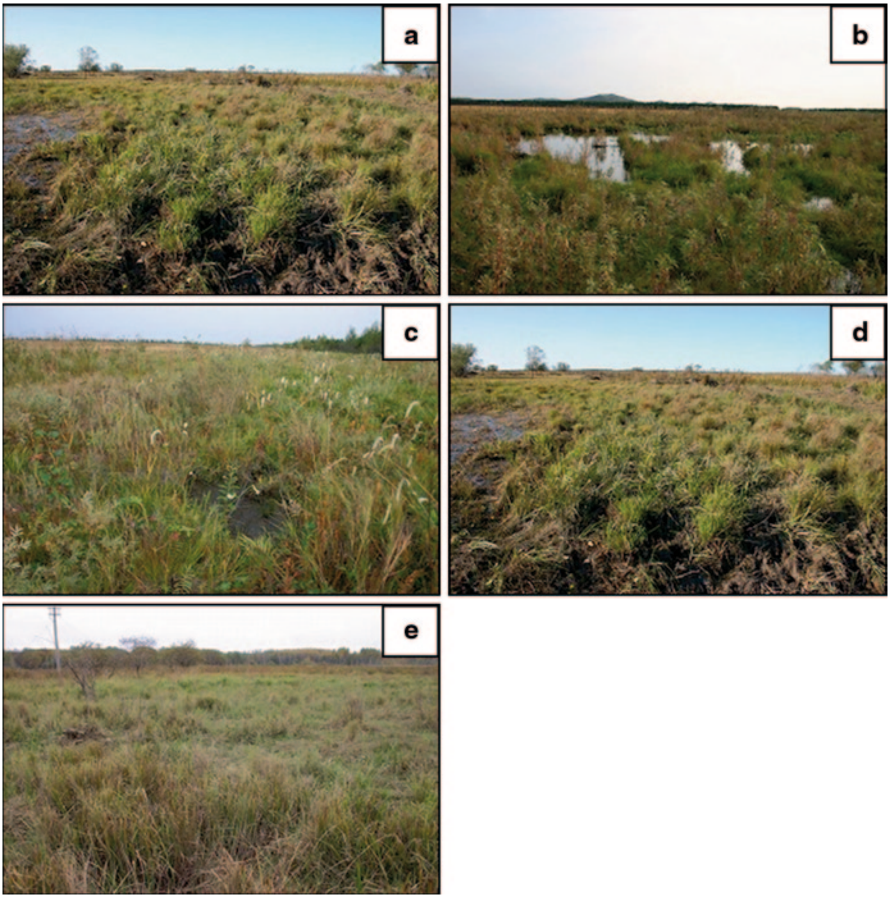


Fig. 3.9 Landscape of wetlands. **a** Alluvial plain; **b** dissected terrace valley; **c** swampy area on terrace; **d** lower floodplain; **e** mountains

vation here should be avoided. Wetlands on the alluvial plains were cultivated before 1992. Wetlands on the higher floodplains were cultivated during 1992–1996.

3.5 Landform and Land Cover in Kiya River Basin

3.5.1 Geographic Setting of Kiya River Basin

The Ussuri River is the major tributary of the Amur River, and contributes 12 % of the Amur River's total discharge (UNEP 2006). The Ussuri flows from Mt. Sikhote-Alini across the border of Heilongjiang Province in China and Primorsky Krai in Russia, into the Amur mainstem.

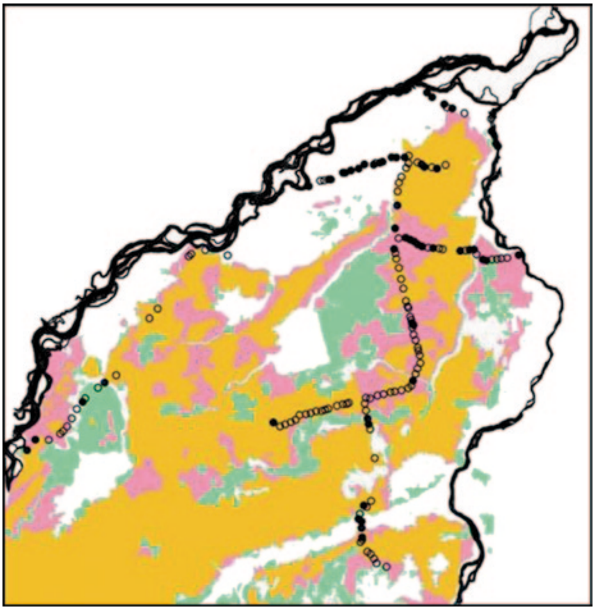


Fig. 3.10 Research points of ground data and cropland from Landsat/TM. ○: cropland; ●: wetland; *black*: water surface; *orange*: cropland in 1992; *pink*: cropland in 1996; *green*: cropland in 2006

Table 3.4 Areas of wetland, cropland, and the other land cover on selected landforms, between 1992 and 1996

				(ha)
		Wetland	Crop land	Others
Alluvial plain	Sep. 1992	3,31,201	7,82,358	3,05,258
	Sep. 1996	1,74,141	9,71,158	2,55,693
Lower flood plain	Sep. 1992	1,29,065	822	38,801
	Sep. 1996	90,023	8,025	70,082
Dissected terrace valley	Sep. 1992	58,108	13,913	70,268
	Sep. 1996	72,912	25,764	43,995
Mountains	Sep. 1992	64,676	11,976	45,215
	Sep. 1996	11,630	22,148	91,074
Swampy area on the terrace	Sep. 1992	18,021	5,429	40,246
	Sep. 1996	23,485	21,300	19,480
Upper flood plain	Sep. 1992	28,461	1,187	13,112
	Sep. 1996	12,338	12,174	16,633

The length of the Ussuri River is 897 km, its catchment area is 193,000 km^2, and the average gradient is 1.73 %. The average discharge is 1150 m^3/s and the average elevation in the river basin is 1682 m. The river frequently has catastrophic flooding. The floodplains are covered by grassland and bush trees and there are ox-bow lakes. There is flooding nearly every year in August and September, with flood water heights typically 3–5 m. Severe flooding occurs once every 10–15 years, with villages, agricultural land, roads, and bridges destroyed (Primpogoda 2012). The Kiya is one of the important branch rivers of the Ussuri River. Its length is 173 km, catchment area 1290 km^2, and average discharge 11.2 m^3/s. There are wetlands

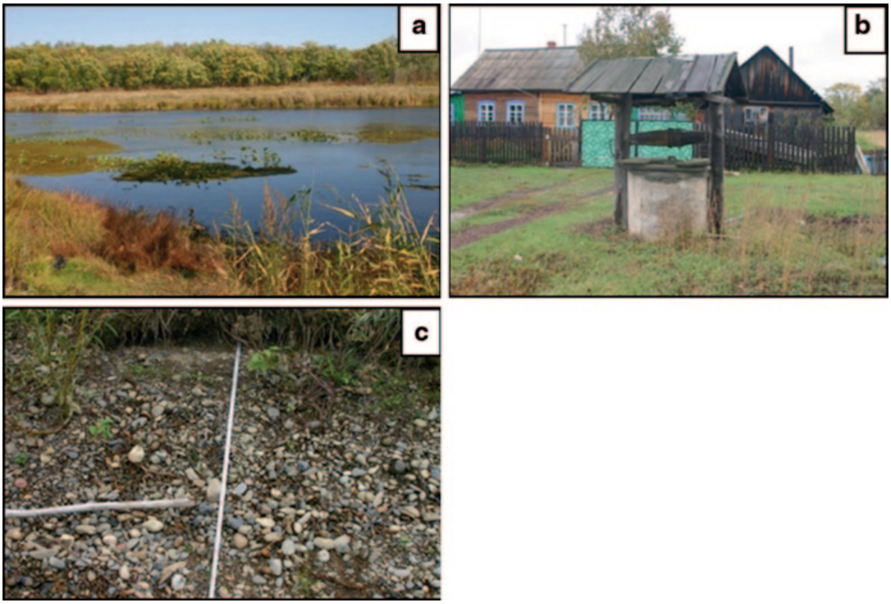


Fig. 3.11 Landscape of Kiya River. **a** Lower floodplain of the river; **b** water well in Vasil'evka Village; **c** Khor River terrace

along the Kiya River floodplain and these are believed to be important in producing dissolved iron flowing into the Amur River (Murooka et al. 2010, 2011). The Khor River is a branch of the Ussuri, but does not produce dissolved iron like the Kiya. The length of the Khor River is 453 km, catchment area 24,700 km^2, and average discharge 11.2 m^3/s. The basin area is 24,700 km^2 and discharge is 386 m^3/s.

Landscapes of the Kiya are shown in Fig. 3.11. Vegetation on the lower river reach consists of *Betula* sp. and other types of low trees, grassland containing Salix, or forest of oak, cedar, and other acicular trees. The area between the Kiya and Khor rivers on the lower reach contains forests of cedar and other types of tall and low trees. The area on the lower reach of the Khor River has grassland, wetland ponds, and forests with Salix and Betula. The middle reach of the Kiya River has peat wetland of Larix kaempferi and Sphagnum, mixed areas of grasses, Bryophyte, pond, and bush on slightly elevated land, cedar forest, and other types of tall and low trees (Soviet Academy of Sciences 1968). Population density is not high around the Kiya River. There are some small towns or villages, such as Marcino Town, Georgiyevka Village, and Ekaterinovka Village.

3.5.2 Land Use and Flooding in Kiya Basin

A submerged area map was constructed and compared with the landform and flood pattern on the geomorphologic land classification map of the Kiya River Basin. The

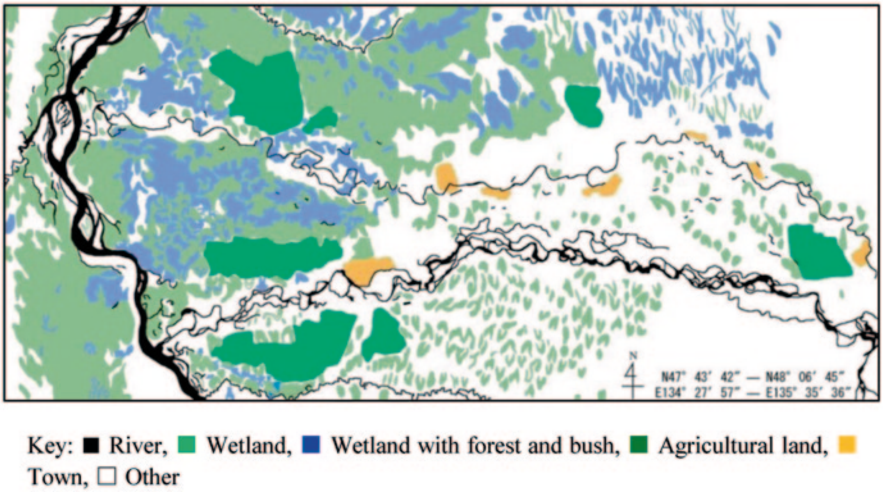


Fig. 3.12 Land cover of the Kiya River Basin

altitude map was represented as a bowl into which water was assumed to be poured. The submerged area map was made for the 33–40 m heights that are typically submerged. The water examination was conducted at points of the Kiya and Khor rivers and water wells. Water quality was measured by a digital pack test (digital water analyzer DPM-MT, Kyoritsu Chemical-Check Lab., Corp.). Amounts of Fe, Fe^{2+}, NO_2, and NO_3 were measured. The measurement range of Fe is 0.05–10 mg/L, that of Fe^{2+} 0.1–10 mg/L, that of NO_3 0.2–10 mg/L, and that of NO_2 0.005–0.5 mg/L. The wetland distribution was from JERS-1/SAR data using NRCS analysis. Available JERS-1/SAR data were eight, but data from when it snowed were not used because snow cover decreases the reliability of the NRCS of JERS-1/SAR data. Moreover, wetland in mountainous areas was not calculated because the NRCS is not reliable on sloping land.

Several former river courses are outlined on the Kiya floodplain. In the view of floodplain sediment, there are alluvial fans along the Khor whose outskirts are dissected by the Ussuri River mainstem. The main courses of the Khor and Kiya rivers are braided. Natural levees developed on the Ussuri River. When precipitation is light, there is submerged area around this river. As the water level increases, the water expands to the lower part of the Kiya and Khor rivers and the Belahun River in China. For example, for water levels greater than 40 m, the floodplain along the Ussuri River and the outskirts of the alluvial fan formed by the Kiya River suffer from stagnant water.

Land cover in the Kiya and Khor river basins is classified as river, wetland, wetland with forest and bush, agricultural land, village, and others (Fig. 3.12). This cover did not change from the 1970s to 2008, when the author conducted field research. The wetlands are near the Kiya River. In particular, wetlands with forest and bush are near this river, but this type is not found near the Ussuri and Khor rivers.

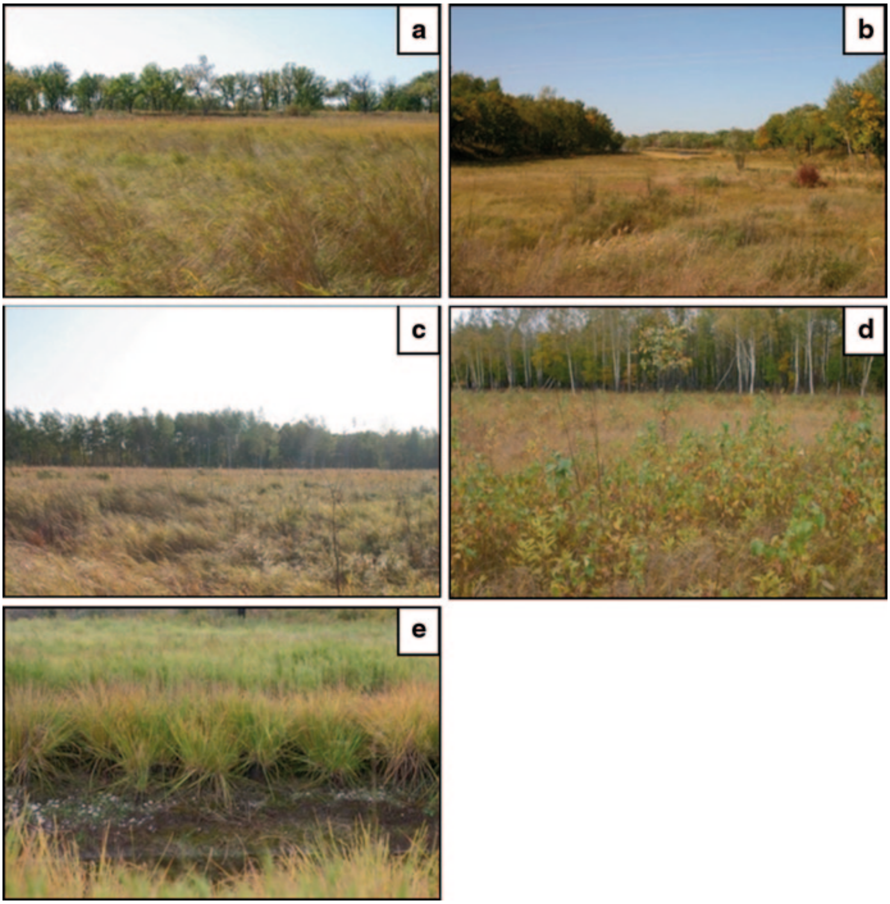


Fig. 3.13 Wetlands on selected landforms. **a** Lower floodplain on lowest reach of Kiya River. **b** Floodplain on lower reach of Kiya River. **c** Lower terrace between Kiya and Khor rivers. **d** Lower terrace of alluvial fan on middle reach of Kiya River. **e** Lower terrace of alluvial fan on middle reach of Khor River

3.5.3 Water Quality Analysis

Water quality was examined as described in Sect. 3.5.2. Water from floodplain wetlands sometimes contained Fe and Fe^{2+}. River water close to the wetland contained Fe, but this was not detected in river water further away from the wetland. Fe was detected in the wetland on the terrace. NO_2 and NO_3 were detected in wells in Marusino and Vasil'evka.

Wetlands are along the Kiya and Ussuri rivers (Figs. 3.13 and 3.14). In May 1995, when precipitation was 55.9 mm, the wetland was small. In August 1997, when precipitation was 232.8 mm, wetlands were extensive on the floodplains of the Ussuri, Kiya, Khor, and Belahun rivers. In September 1992 and September

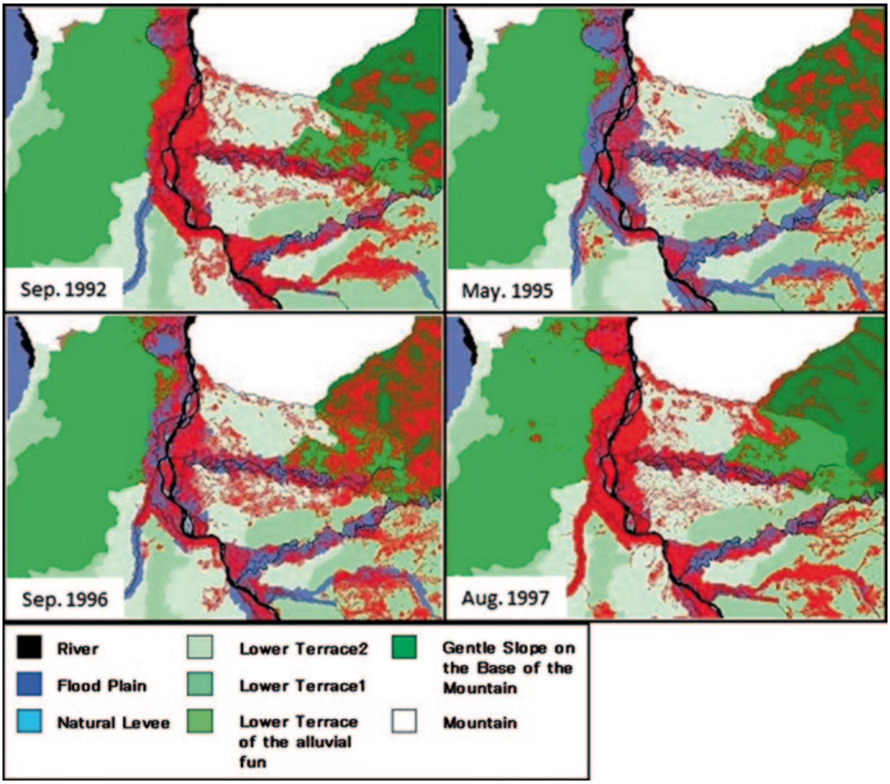


Fig. 3.14 Wetland distributions (Precipitation was 120.9 mm in Sep 1992, 55.9 mm in May 1995, 147.9 mm in Sep 1996, 232.8 mm, in Aug 1997)

1996, precipitation was 120.9 and 147.9 mm, respectively. Wetlands on the floodplains were larger in September 1992, but wetlands on the terraces were larger in September 1996.

Fe was detected in wetlands on the floodplain of the Kiya River, which was a flat reedy bed. In the Khor River Basin, the heaps of Calex spp. were tall and a dead shell was found among the heaps of Calex spp. Quercus crispula plants were found only in the lower part of the Kiya River. Betula spp., which were vegetation in the dry area, were found in other locations. Thus, it is believed that the groundwater level was low in the lower Kiya River, and major flooding had been rare. Well water contained NO_2 and NO_3, which was probably the result of agricultural chemicals. When precipitation increases, wetland areas on the floodplain expand. There was little wetland in the Chinese region, especially in the area west of the Belahun River. This was because the wetland in China had been cultivated. Wetlands on the floodplain increased and decreased substantially, but there were always wetlands on the lower terrace between the Kiya and Khor rivers. It is thought that a clay layer blocks surface water from flowing underground. Despite the greater rainfall and resultant wetland distribution, wetlands did not spread over the floodplains when precipita-

Fig. 3.15 Flood locations near the Amur River. **a** Submerged cropland of XiaoHeZi village and the Amur River. **b** Landscape of XiaoHeZi village

tion was abundant, as in the Kiya and Khor river area during August 1997. That is, floodplain wetlands were dependent on precipitation, but not so wetlands on the terraces. Major flooding is rare in the wetland around the Kiya River, so the reedy bed was the principal vegetation. We speculate that the wetlands around this river were always submerged and dissolved Fe was readily produced. It appears that the Khor River Basin does not have a peat layer but does have a gravel layer; we speculate that the dissolved Fe produced readily flowed into the soil below the Khor River.

3.6 Flooding and Landforms

3.6.1 Floods and Discharge

Liu et al. (1996) listed flood years on the Ussuri River as 1915, 1927, 1971, and 1981. Although there are flood records for this river, there are few for the Amur River. Interviews indicated that the most severe flood was in 1984, with a water level of 85 cm inundating XiaoHeZi village (Fig. 3.15), 9 km east of Fuyuan at an altitude of 57 m. Another severe flood occurred in 1998, with 80 cm water depth covering TuanJie village (altitude 41 m), 16 km southeast of Fuyuan. The nearest river to these villages is a tributary of the Amur, and the altitude of the nearest point of the river was ~31 m.

We obtained discharge data on the mainstem and several major tributaries of the Amur River from the Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) and Global Runoff Data Center (GRDC) in Koblenz, Germany. There were daily data from 1 January 1940 to 31 December 2000. There were monthly average data from January 1960 to December 2006 (except for 2005). Velocity of the current on a vertical plane across the river on the observation line was measured. Discharge was calculated by integrating this velocity. An observation boat crossed this line on the day of observation. There were ten observation points. At each point, current velocities at five equal depths were measured accurately. Observation frequency was about four per month during the Soviet era, about one per month afterward. Observations were more frequent when the water level varied greatly (Tachibana 2003).

Ogi et al. (2001) researched monthly average discharge data from 1964 to 1984 in Komsomolsk-on-Amure, and Tachibana et al. (2008) studied such data from 1964 to 1984 at Godroskoe. The results showed that discharge of the Amur River had two peaks, in spring (May) and autumn (September), and minimal values in July. The two peaks were affected by preceding vapor fluxes which was flowing of water vapor made by the difference of moisture, from the preceding September through April, and May through August, respectively (Tachibana et al. 2008). Precipitation and temperature data were downloaded from the Climate Explorer (http://climexp.knmi.nl/start.cgi?someone@somewhere) of the Royal Netherlands Meteorological Institute (KNMI) website. Data used were monthly precipitation and monthly temperature at Khabarovsk from January 1891 through July 2004. The observation point was 48.53 °N, 135.23 °E.

3.6.2 Mann-Kendall Test

Parameters used in the Mann-Kendall test were the discharge, precipitation, and temperature data. Monthly averages were analyzed for each parameter. The Mann-Kendall test is often used to assess the direction of time series because it is rarely affected by outliers and no-data periods (Nishioka and Takara 2003). This is a non-parametric test to determine whether the null hypothesis is correct. This hypothesis is that a time series is independent and has the same probability distribution. The analysis period was January 1940 through July 2004 for the discharge data. Time series of temperature, precipitation, and discharge were subjected to the Mann-Kendall test. The monthly discharge data were averages of daily data from 1940 through 2000. The test of annual average discharge, temperature, and precipitation revealed a significant ascending trend for temperature and precipitation and a significant descending trend for discharge (Fig. 3.16). The rising temperature agrees with Tachibana et al. (2008), who asserted that temperature was increasing in Eurasia, especially in the Amur River Basin and Sea of Okhotsk, because the North Atlantic Oscillation was positive. Furthermore, there was a significant increase of minimum discharge and a significant decrease of maximum discharge. The temperature was sometimes less than 1 °C before 1980, but did not drop below this mark afterward.

The oscillation of temperature was greater during 1940–1970 than during 1970–2003. The heaviest precipitation was in 1981 and second heaviest in 1962. The discharge oscillation was considerable during 1940–1956. There were declining trends of discharge during 1960–1968, 1973–1979, and 1998–2002. There was a rising trend of discharge during 1967–1971.

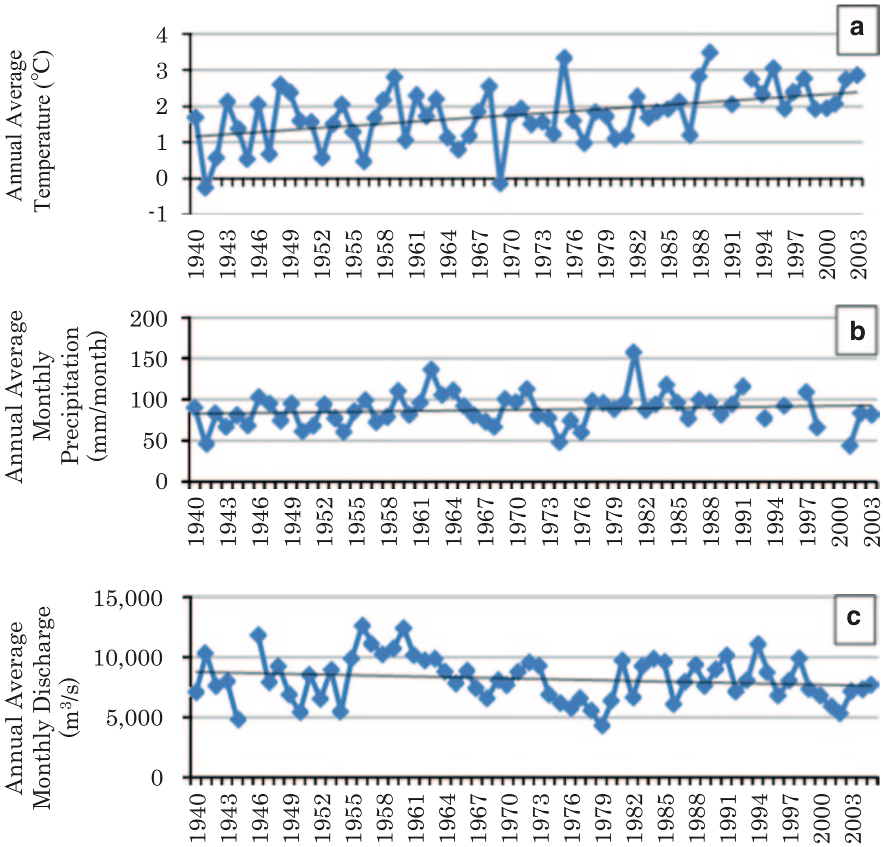


Fig. 3.16 Time series of annual average temperature (**a**), annual average monthly precipitation (**b**), and annual average monthly discharge (**c**)

3.6.3 Relationship Between Land Use and Floods

On the Sanjiang Plain, soybean, corn, and wheat were cultivated (Fig. 3.17). The price of rice doubled and tripled after the 1992 liberalization of circulation and sales in China (Sakon 2000). Soybean fields decreased and paddy fields increased drastically from the mid-1980s in Heilongjiang Province. State farms took up about one third of the area of the Sanjiang Plain. Because the Chinese government invested in these farms (Zhang and Kako 2004), they were important for developing paddies (Park et al. 2010). State farms produced more data than did ordinary agricultural villages. In the present study, the history of land use change on state farms was defined as a human impact. Park et al. (2010) summarized the history of this change for the Sanjiang Plain. In the first stage (1947—early 1960s), state farms were established, and reclamation and irrigation were the main land use change. In the second stage (mid 1960s–1970s), bank construction was initiated on the lower river reaches of the plain. In the third stage (mid 1970s–1980s), floods were modulated by irri-

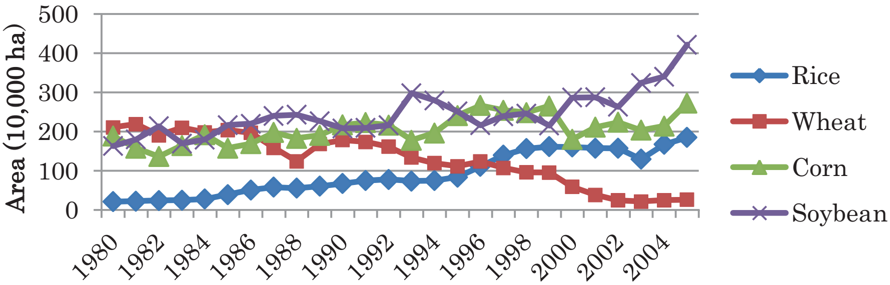


Fig. 3.17 Transition of agricultural land. (Source: Heilongjiang Statistical Yearbook 2006)

gation based on the *Scheme for Flood Modulation by Irrigation in the Sanjiang Plain* by the Committee of Development and Conservation of the Sanjiang Plain. Furthermore, Haruyama (2009) described the first development of the *Agricultural Development Project* in 1988. This introduced the concept of drainage projects to adequately drain agricultural land to prevent flood disasters on the Sanjiang Plain with substantial wetland. Drainage ditches were dug about every 200–400 m.

In general, when land use is changed, climate is altered by modifying the area of nonabsorbent soil, the amount of water vapor, and others, or by increasing CO_2 emission through forest logging. These factors lead to depletion of the water resource or to the degradation of biodiversity. On the Sanjiang Plain, wetland reclamation leads to ground water deterioration or to increased area of nonabsorbent soil, and ultimately to increased discharge into the Amur River. Time series of annual temperature and precipitation for the Sanjiang Plain were increasing, while that of discharge was decreasing. This means that human activity affects discharge more than climate.

The time series of minimum discharge varied with the history of irrigation and flood control on the Sanjiang Plain (Fig. 3.18). Almost all minimum discharges were in March, just before snowmelt. The minimum discharge increased from reclamation and drainage during 1947–1961, decreased from bank construction during 1962–1975, and fluctuated slightly but steadily increased because of dams and irrigation during 1976–1987. This discharge drastically increased because of irrigation and intensive conversion of crop fields to paddy fields during 1988–1997, and slightly decreased because of dam construction after 1998. That is, the minimum discharge rose because of water from wetlands reclaimed and drained during 1947–1961. Discharge decreased because banks blocked water flow from land to rivers during 1962–1975. Discharge fluctuated slightly and steadily increased because of dam construction and degradation of water holding capacity of wetlands through conversion to crop fields. Discharge drastically increased because drainage was improved by introducing drainage equipment, and groundwater was pumped up and flowed into the Amur River by converting crop fields to paddy fields. This was done because of a steep rise in the price of rice during 1988–1997.

Discharge decreased and remained stable beginning in 1998, because the Long Tou Qiao Dam construction began in that year. Discharge was high in 1972 and

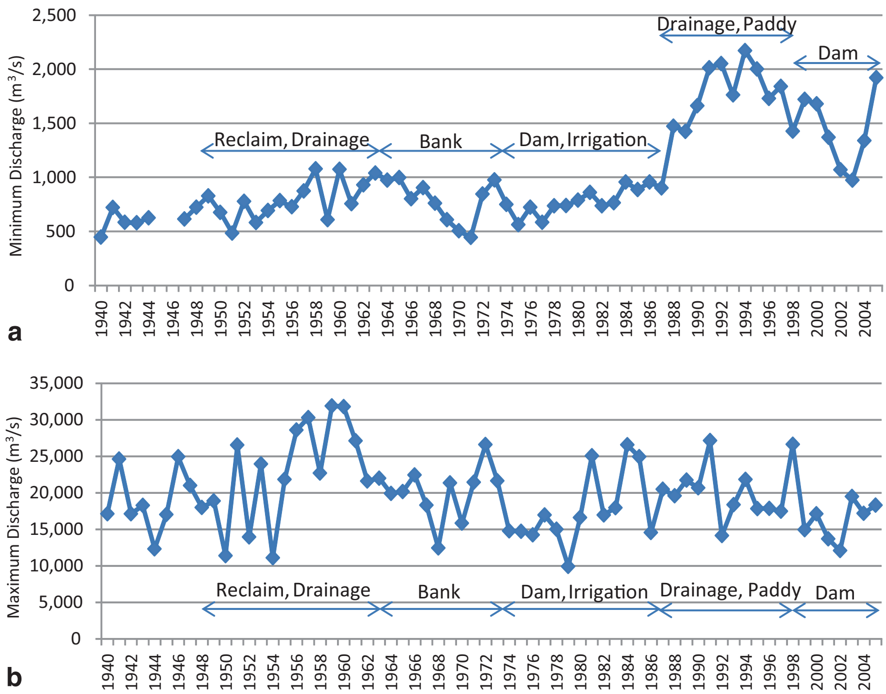


Fig. 3.18 Time series of minimum (**a**) and maximum (**b**) discharges

1973, because of heavy precipitation in 1969, 1970, and 1971. Discharge was low in 2002 and 2003, because precipitation in the summers of 2001 and 2002 was low (149 and 375 mm, respectively) relative to the average of over 400 mm. Minimum discharge apparently varied with human activity on the Sanjiang Plain, as described above.

Maximum discharge is important because it is directly linked to flooding. Strong Asian monsoons sometimes increased discharge in autumn (Tachibana 2008). Time series of maximum discharge were affected by precipitation but roughly corresponded with those of minimum discharge (Fig. 3.14). Maximum discharge increased during the reclamation and drainage period of 1947–1961, remained stable or declined during the bank construction of 1962–1975, and remained stable or increased during the dam and irrigation period of 1976–1987. This discharge remained stable or increased during the drainage and paddy field period of 1988–1997, and declined or remained stable during the dam period after 1998. That is, maximum discharge varied with the minimum discharge during the irrigation and drainage of 1947–1961, dam construction period of 1962–1975, and the dam and irrigation period of 1976–1987. In the drainage and paddy field period of 1988–1997, groundwater was pumped up because of the conversion of crop to paddy fields, but water was held on the surface of the latter fields in summer. As a result, maximum discharge did not increase or decrease. In the dam period from 1998, maximum discharge was low and stable because flood control was developed.

Minimum discharge had an ascending trend because water holding capacity decreased owing to wetland reclamation and pumping of groundwater. Maximum discharge declined because flood control was developed. Discharge was kept low by banks and dams. Flood control establishment was effective. However, floods occurred more often because of the reduced water holding capacity caused by the land use change. Finally, we concluded that human impacts on the Sanjiang Plain increased flood frequency.

3.7 Conclusion

The Sanjiang Plain has been cultivated intensively for a short period of several decades, and this cultivation has been widespread. As a result, natural hazards occur more often than before. The authors made a detailed geomorphological map and clarified land cover change in recent years on the plain. The Kiya River Basin, where land cover did not change, was investigated and compared with the Sanjiang Plain. Furthermore, floods on the Amur River were analyzed. Finally, the effect of land cover change on the environment was studied. Dealing with data of rivers in developing areas like the Amur Basin, especially international rivers, is difficult because they are sometimes state secrets. The data are rarely made available. In the present study, the author obtained data, although they are limited. Analyzing floods with such limited data was successful in this case. On the Sanjiang Plain, human activity such as the expansion of agricultural land has made natural hazards such as increasing flood frequency more serious. Wetlands serving as flood control basins were converted to agricultural lands. Damage from the natural hazards worsened because of the expansion of poorly planned land use in the area. Discharge of the Amur River has been altered by human activity. This means that such activity affects the water holding capacity of the Sanjiang Plain. In conclusion, human activity increases floodfrequency. The environment of the natural wetland readily produces Fe, which affects biomass in the Okhotsk Sea. These conditions were evident in the Kiya River Basin. On the Sanjiang Plain, the wetlands were destroyed. It is important to conserve wetlands, which in turn will contribute to saving the natural environment.

References

China Statistics Press (2006) HeilongJiang Statistical Yearbook, Beijing (in Chinese)

Frost VS, Stiles JA, Shanmugan JA, Holtzman JC (1982) A model for radar images and its application to adaptive digital filtering of multiplicative noise. IEEE Trans Pattern Anal Mach Intell 4(2):157–166

Ganzey SS (2005) Transboundary geo-systems in the south of the Russian Far East and in Northeast China, Pacific Institute of Geography. Dalnauka, Vladiovostok

Ganzey SS, Ermoshin VV, Mishina NV (2010) The landscape changes after 1930 using two kinds of land use maps (1930 and 2000). Report on Amur-Okhotsk Project, vol 6, pp 251–262

Haruyama S (2009) River environment changing and response of the Sunghua River where is the Wetland Area in the Northeast China. Ser Inst Asian Stud Res Asia 72:3–24

Heilongjiang Bureau of Statistics (1991–1999) Statistical yearbook of Heilongjiang (1991–1999). Harbin

Japan Photogrammetory Associates (1998) Synthetic aperture radar handbook. Asakura Publishing, Tokyo, pp xii+199 (in Japanese)

Liu B, Tang J, Jin Y (1996) Flood characteristics and disaster in Wusuli River. China Acad J Electron Publ 1996(1):92–94 (in Chinese),

Masuda Y, Haruyama S, Kondoh A, Murooka M (2006) Grasp of Land use change in Amur River Basin using NDVI derived from NOAA/AVHRR PAL dataset. J Rural Plan Assoc 25:245–250

Murooka M, Haruyama S, Yamagata K, Kuwahara Y (2010) The wetland distributions of the Kiya River using remote sensing. Report on Amur-Okhotsk Project, vol 6, pp 161–168

Murooka M, Kuwahara Y, Haruyama S, Yamagata K, Kondoh A (2011) Wetland distribution and the properties of water around Kiya River in Russia. Abstract of Association of Japanese Geographers 2011 Spring, 150 (in Japanese)

Nishioka M, Takara K (2003) A trend analysis of hydrological time series by Mann-Kendall test. Annu Disas Prev Res Inst Kyoto Univ 46B:181–192

Ogi M, Tachibana Y, Nishio F, Danchenkov MA (2001) Does the fresh water supply from the Amur River flowing into the Sea of Okhotsk affect sea ice formation? J Meteor Soc Japan 79(1):123–124

Ogura N, Yamamoto K (2005) Human impact and river eco-system. Gihodo Shuppan, Tokyo

Park H, Zhang J, Sakashita A (2010) Characteristics of agricultural development on Sanjiang plain—development of paddy fields of state farm from a macroscopic perspective (in Japanese). Rev Agric Econ Hokkaido Univ 65:83–100

Primpogoda (2012) Ussuri River. http://www.primpogoda.ru/articles/reki_primorya/reka_ussuri/. Accessed 15 Feb 2014 (in Russian)

Sakon T (2000) What is Chinese paddy? Tasty 13(3):9–14

Shiraiwa T (2011) Global environment of giant fish breeding forest-changing Amur River Basin. Showado, Tokyo, pp 136–137

Soviet Academy of Sciences (1968) The vegetation map of Amur River Basin. Soviet Academy of Science publishing, Russia

Tachibana Y (2003) Discharge fluctuation and mechanism of the Amur River. Report on Amur-Okhotsk Project, vol 1, pp 26–30

Tachibana Y, Oshima K, Ogi M (2008) Seasonal and interannual variations of Amur River discharge and their relationships to large-scale atmospheric patterns and moisture fluxes. J Geophys Res. 113(D16102):14

Umitsu M (1980) Land form of the Sanjiang plain in China. Bull Ehime Univ (Second Number) 12:93–99

UNEP (2006) Global international waters assessment regional assessment 30 Sea of Okhotsk, pp 17–18. http://www.unep.org/dewa/giwa/areas/reports/r30/giwa_regional_assessment_30.pdf. Accessed 15 Feb 2014

Zhang JP, Kako T (2004) Development of the rice cultivation in the Heilongjiang national park. Proceedings for Workshop and Conference on World Japonica rice marketing and production potential "Implications from Low World/Domestic Rice Prices, Kyoto, Japan". http://worldfood.apionet.or.jp/web/6.htm. Accessed 15 Feb 2014

Chapter 4
Changes in Wetland and Floodplain Sedimentation Processes in the Middle Reach of the Amur River Basin

Kotaro Yamagata, Shigeko Haruyama, Mizue Murooka and Dexuan Wang

Abstract Remarkable land-cover changes have recently occurred in the Amur River Basin. In particular, cultivated area has increased in China, while deforestation has advanced in Russia. It is possible that these land-cover changes will affect the hydrologic environment of the Amur River and the movement of material through the river. We reconstruct historical environmental changes in the Amur River Basin using floodplain sediments. We focused on the Sanjiang Plain in Northeast China, which is on the middle reach of the Amur River. We investigated sediment profiles on the floodplains of the river and its tributaries from outcrops or sediment cores obtained by hand boring. These confirmed recent coarsening of fluvial deposits at many locations on the floodplain, along the Amur, Songhua, and Ussuri rivers. Here, silt-clay layers were covered by 30–70 cm-thick sandy deposits. We postulate that the grain size coarsening of the floodplain deposits ensued from an increase in peak discharge and coarse material supplied by farmland expansion and forest reduction.

Keywords Amur River • Sanjiang plain • Fluvial deposit coarsening • Flood plain • Land cover change

K. Yamagata (✉)
Division of Social Studies, Joetsu University of Education, Joetsu, Niigata 943-8512, Japan
e-mail: kotaro@juen.ac.jp

S. Haruyama
Graduate School of Bioresources, Mie University, Mie, Japan

M. Murooka
Hokkaido Abashiri Fisheries Experimental Station, Yoichi, Japan

D. Wang
Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences, Changchun, China

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_4

4.1 Introduction

Deforestation and agricultural land use greatly influence fluvial processes, including erosion, sediment transport, and deposition (Brooks and Brierley 1997). More specifically, agricultural cultivation can increase soil erosion, river discharge, and sedimentation levels within a drainage basin (Lang and Hönscheidt 1999). Recently, there have been remarkable land-cover changes in the Amur River Basin (Ganzey et al. 2010; Haruyama et al. 2008). It is possible that these changes will affect the hydrologic environment of the Amur River and the movement of material through that river. We examined the relationship between changes of land cover and the hydrologic environment in the Amur Basin, based on data of floodplain deposits along the river. These deposits created by erosion, transport, and deposition can be regarded as a medium that records changes of the hydrologic environment of the river (e.g., Walling 1997; Neal et al. 1998). Therefore, our aim is to reconstruct long-term hydrologic environmental change accompanying the land-cover change in the Amur River Basin, using floodplain deposit data.

4.2 Amur River Basin and Recent Land-Cover Change

The Amur River, which has a basin area more than 2 million sq km and a stream length of 4350 km, is one of the longest rivers in the world. It is also an international river. Its source is in Mongolia and it collects water from tributaries in China and Russia, from where it finally flows into the Sea of Okhotsk (Chap. 3, Fig. 3.1). Recently, there has been a remarkable change of land cover in the Amur River Basin. Land-use change between the 1930s and 2000 in the basin is shown in Fig. 4.1. This figure shows a reduction in grassland and wetland areas, and an increase in farmland area. Such change is remarkable, particularly in China where the area under cultivation has rapidly expanded over the past 20 years. In contrast, such farmland expansion has not been reported in Russia. However, there are reports of increasing deforestation and forest fire frequency. Such land-cover changes could affect the basin hydrologic environment and the movement of material through the river.

It is difficult to investigate sediments throughout this vast basin. Hence, in this study, we surveyed the Sanjiang Plain, which is on the middle reach of the Amur River. This plain is near where the mainstem of the Amur River meets major tributary streams of the Songhua and Ussuri rivers. Furthermore, the plain has had some of the most remarkable land-use change in recent years. A large area of the plain was covered by natural wetlands in 1976, but most of these were converted to agricultural land by 2005 (Fig. 4.2). At present, farmland has spread near the tops of the hilly land, and development of gullies on such farmland on hillslopes in the area surrounding the Sanjiang Plain has been detected. Satellite images from the period such agricultural lands were being developed show that forests on hilly lands were clear-cut logged at many locations and that the soil was widely exposed. Present riverbed sediments of rivers flowing out of such hilly land show larger gravel sizes

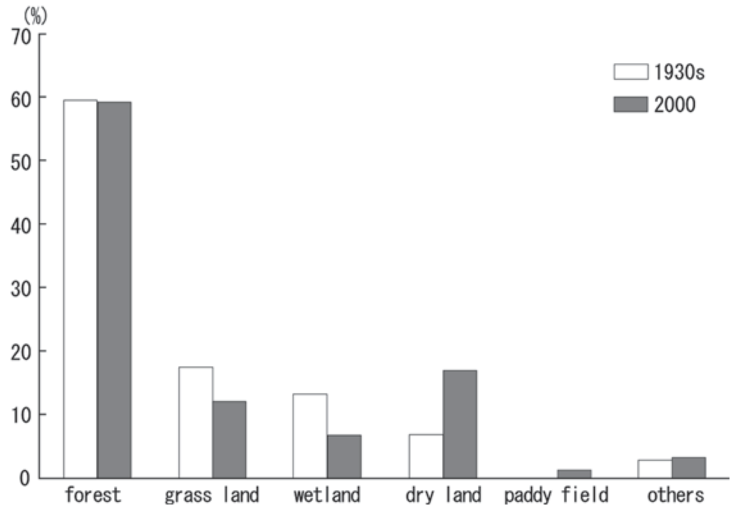


Fig. 4.1 Tendency of the change in main land use type in the Amur River Basin. (Ganzey et al. 2008)

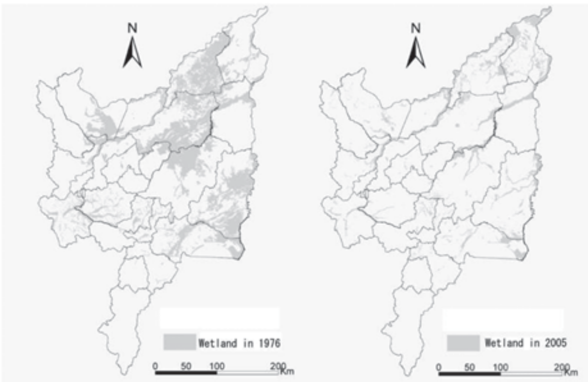


Fig. 4.2 The area of wetlands in the Sanjiang plain in 1976 and 2005. (Song et al. 2007)

compared with the present flow rate. Thick sand layers have been observed around the river courses. Such situations suggest that the outflow of sediment from these rivers were more active during the period of agricultural development.

4.3 Geomorphological Features of Sanjiang Plain

The Sanjiang Plain is more than 800 km inland from the mouth of the Amur River. The plain is in the middle reach of that river and is an intermountain basin formed during the Quaternary period by intensive subsidence caused by tectonic movements. Basin topography was also altered by climate change and human activity

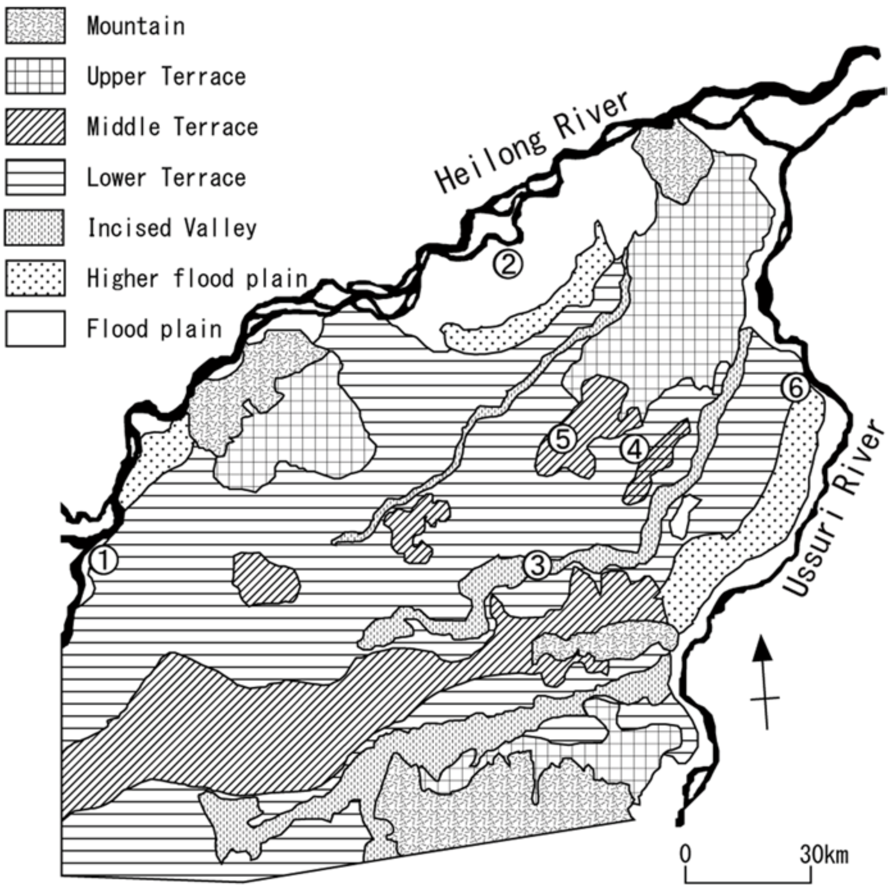


Fig. 4.3 Geomorphological surface distribution map of Sanjiang plain

during the Pleistocene and Holocene epochs. Most of the basin floor was covered by a fluvial surface. Geomorphology of the alluvial plain is a key consideration for understanding the region's fluvial processes.

The basin is at very low altitude and is a very flat plain, most of it below 60 m a.s.l. However, several topographic surfaces can be distinguished when viewed in detail. Murooka and Haruyama (2014) constructed a geomorphological classification map of the Sanjiang Plain based on remote sensing and altitude data from the Shuttle Radar Topography Mission (Chap. 3, Fig. 3.6). Figure 4.3 is a geomorphological surface distribution map for the northeastern part of Fig. 3.6 in Chap. 3, constructed by adding field survey results. Lower terraces 1 and 2 and middle terraces 1 and 2 are described together, because a clear terrace scarp between them was not evident in the field study.

Topography of the Sanjiang Plain is classified into the present streambed, present floodplain, higher floodplain, fluvial terraces (lower, middle, and upper), and

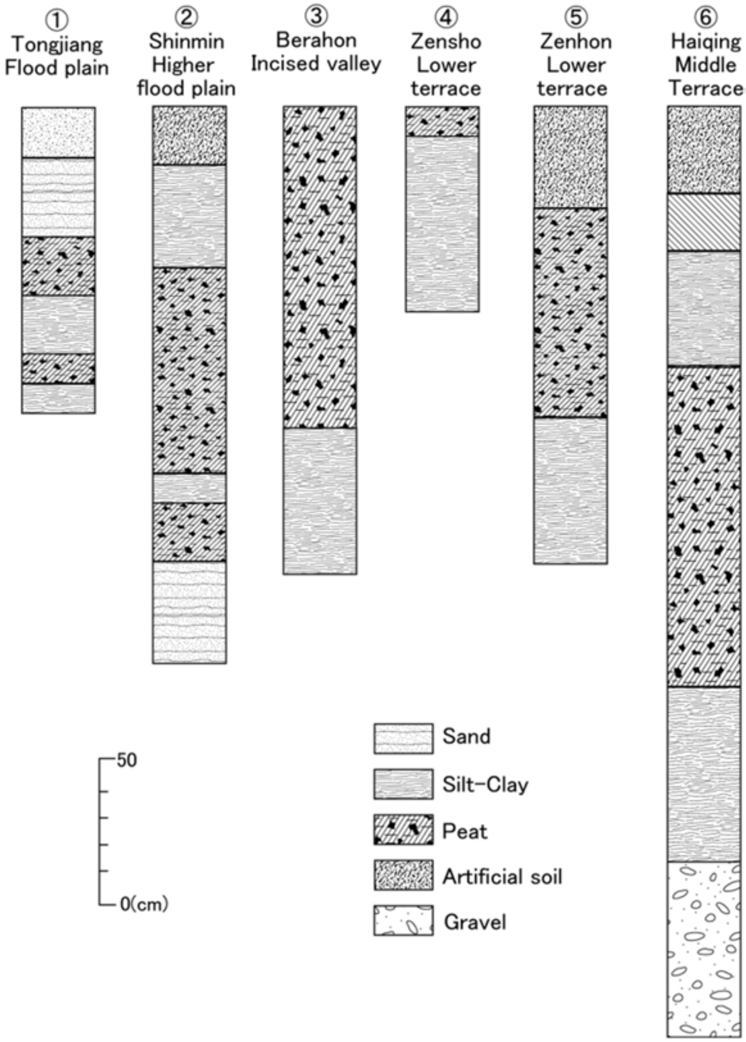


Fig. 4.4 Columnar sections of floodplain deposits on Sanjiang plain. Locations are shown in Fig. 4.3

hilly area. Figure 4.3 shows that most of the basin is occupied by terraces, and the present river flows on the floodplain, shallowly dissecting the lowest terrace. A large swampy area occupies the center of the plain as well as the upper and middle terraces surrounding the plain. This geomorphological setting indicates that tectonic subsidence has been continuous since the early Quaternary to Holocene.

We examined and compared the deposit profiles on each surface (Fig. 4.4). There is a sand gravel layer at the base of the deposits. The middle terrace is also composed of thick gravel deposits. Although not shown in Fig. 4.4, we confirmed in a gravel extraction pit that the lower terrace also consists of thick gravel deposits.

Thus, the terraces are assumed to have been formed during cold glacial periods, when the production of debris was very active in mountains.

The coarse deposit layers are covered by layers of silt-clay spanning a few meters. A peat layer covers these layers. These profiles are considered to reflect the sequence of processes from deposition to the emergence of terraces. But, only the present floodplain peat and clay layers are covered by sandy deposits.

The wetlands are on terraces covered by clay sediments and on the floodplains and incised valley floor. There are peat sediments in most of the wetlands, and thickness of the peat deposits varies with topography. Most peat deposits currently forming on the floodplains along the Heilongjiang, Songhua, and Ussuri rivers are less than several tens of centimeters thick. In contrast, thick peat deposits are found on the incised valley floor.

In Table 4.1, basal ages of peat deposits reported in previous studies and the geomorphic surface at each point are summarized. The ages at these points, which are classified as mountain, are younger than 3 ka. These points are in wetlands developing along the present flowing river in the mountains.

In contrast, ages obtained on the terraces have a wide range. The oldest, obtained on the upper and middle terraces, are 9525 ± 125 year BP (upper), and 36,300 ± 1500 year BP (middle). The middle terrace is older, but the upper one is higher. Therefore, it is believed that both terraces were formed before Marine Isotope Stage 3 (MIS 3; ca 24–59 ka BP). The oldest age obtained on the lower terrace is 5910 ± 170 year BP. Because there is an age of 9420 ± 70 year BP from the dissected valley of the lower terrace, it is believed that the lower terrace is younger than MIS 3, but older than the Holocene.

Therefore, it is presumed that the lower terrace formed during the cold period of MIS 2 and the middle terrace during the cold period of MIS 4. The peat deposits, with age 36,300 ± 1500 year BP, likely formed during the relatively warm period of MIS 3. Although there are no data directly indicating the age of the upper terrace, its fragmentary distribution and the clear height difference between the lower and middle terraces suggest that it formed during the glacial period before the last Ice Age.

Therefore, each terrace is considered to have formed during the last glacial age or earlier cold period. However, most basal ages of the peat layers on the terraces are within the Holocene. These peat layers do not entirely cover the terrace surfaces, but are instead in the swampy area and dissected valley on those terraces. Ages 9420 ± 70 year BP through 1285 ± 75 year BP were determined in the dissected valley. In the present dissected valley, rivers such as the Naoli and Bielahong flow with frequent meanders. In this valley formed by terraces that emerged after the Last Glacial Maximum, the peat deposits began to form under the warming climate during the Holocene. During that period, owing to the deposition of material in the back marsh by the meandering rivers, there is a wide range of basal peat ages.

Distributions of swamp, swampy meadow, and wetland in the dissected valleys on the lower terrace around location 3 in 1974 are shown in Fig. 4.5. Swampy areas are scattered across the very flat terrace surface. The ages of peat obtained from these areas include some ca. 14 ka BP of the Bølling-Allerød warm period.

Table 4.1 Basal ages for peat profiles on each geomorphic surface

Site name	Latitude (N)	Longitude (E)	Geomorphic Surface	^{14}C age (yr BP)	References
Qianjinlinchang	45° 06’	130° 46’	Mountain	2,910±80	Yan et al. 2014
Shenjiadian2	46° 36’	130° 38’	Mountain	2,541±80	Yan et al. 2014
Shenjiadian1	46° 36’	130° 38’	Mountain	2,470±80	Yan et al. 2014
Huachuan	47° 01’	130° 43’	Mountain	2,375±167	Yan et al. 2014
Shenjiadian			Mountain	1,700	Igarashi et al. 1987
Qindeli3	48° 00’	133° 15’	Upper terrace	9,525±125	Yan et al. 2014
Fuyuan	48° 21’	134° 17’	Upper terrace	9,300±100	Yan et al. 2014
Qindeli2	47° 58’	133° 8’	Upper terrace	1,790±200	Yan et al. 2014
Bielahonghe4	47° 31’	134° 04’	Middle terrace	36,300±1500	Yan et al. 2014
Bielahonghe5	47° 31’	134° 4’	Middle terrace	36,300±1500	Yan et al. 2014
Qianjin Farm1	47° 33’	133° 10’	Middle terrace	14,277±230	Yan et al. 2014
Qianjin Farm2	47° 33’	133° 10’	Middle terrace	14,277±230	Yan et al. 2014
Dongshenggong-she	46° 29’	132° 28’	Middle terrace	6,954±105	Yan et al. 2014
Bielahonghe2	47° 31’	134° 04’	Middle terrace	5,650±90	Yan et al. 2014
Bielahonghe3	47° 31’	134° 04’	Middle terrace	5,650±95	Yan et al. 2014
Bielahonghe1	47° 31’	134° 04’	Middle terrace	4,615±75	Yan et al. 2014
Dongsheng	46° 37’	132° 31’	Middle terrace	4,417±307	Yan et al. 2014
Jinlong	46° 32’	132° 35’	Middle terrace	4,027±308	Yan et al. 2014
Shen Dao	47° 21’27”	133° 52’36”	Middle terrace	5,650±95	Yang 1988
Tongjiang	48° 05’	133° 15’	Lower terrace	4,917±120	Yan et al. 2014
Hai Hai Gong Lu	47° 55’4”	134° 28’6”	Lower terrace	5,910±170	Bao et al. 2011
Sheng Dao	47° 35’28”	133° 38’49”	Lower terrace	3,428±167	Bao et al. 2011
Qiangfeng	47° 35’41”	133° 47’1”	Lower terrace	2,990±190	Bao et al. 2011
Honghe	47° 47’22”	133° 37’43”	Lower terrace	2,897±143	Bao et al. 2011
Qindeli1	47° 55’35”	133°13’4”	Dissected Valley	9,420±70	Yan et al. 2014
Sheng Dao	47° 15’49”	133°45’42”	Dissected Valley	3,912±193	Bao et al. 2011
Beidawan	47° 32’20”	133° 41’00”	Dissected Valley	3,075±70	Bao et al. 2011
Honghe			Dissected Valley	1,285±75	Yang 1988
Honghe			Dissected Valley	2,300	Igarashi et al. 1987
Qinghe Reservoir	46°36’	132°57’	Floodplain	1,610±200	Yan et al. 2014
Baoqing	46°36’	132°57’	Floodplain	1,585±90	Yan et al. 2014
Qinghe Reservoir2	46°35’	132°58’	Floodplain	1,585±90	Yan et al. 2014
Qinghe Reservoir1	46°35’	132°58’	Floodplain	1,425±90	Yan et al. 2014
Fuyuan			Floodplain	1,655±75	Yang 1988
Baoqing			Floodplain	1,464±90	Yang 1988

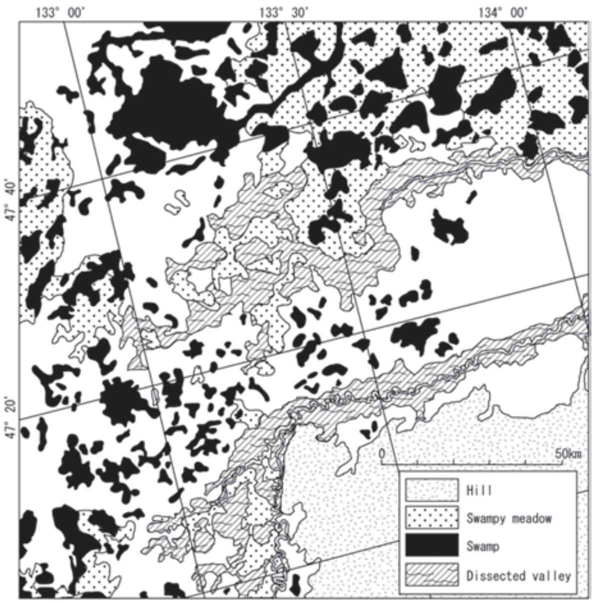


Fig. 4.5 Distribution of swamp and swampy meadow on lower terrace in 1974. (After Li et al. 1989)

However, the majority of these areas are included in the Holocene, and most are concentrated in the period after the Hypsithermal.

From the distribution, morphology, and age of these swampy areas, it is estimated that their origin may be thermokarst. In the present Sanjiang Plain, overwintering permafrost is sparsely scattered in peaty marsh. However, it is thought that thick permafrost widely covered the terrace surface of the Sanjiang Plain during the last Ice Age. The peat deposits probably developed in swampy areas in the depression formed during permafrost melt under the warming climate following the last Ice Age.

Ages obtained from the floodplain, which developed along major rivers such as the Ussuri and Heilongjiang, are relatively recent, from 1.2 to 1.6 ka. In these rivers with broad mountainous areas and cold regions upstream, deposition and erosion have been active. Therefore, peat began to be deposited only recently. Thus, the floodplain environment is unstable and very sensitive to environmental change.

4.4 Flood Plain Deposits on Sanjiang Plain

Swamps and wetlands are topographic units of greatest interest for iron production and river transportation. Because a large area of the Sanjiang Plain is occupied by wetlands, it is important for the production and transport of iron to the Amur River mainstem. However, wetland area on the plain has been decreasing rapidly in recent years because of farmland encroachment.

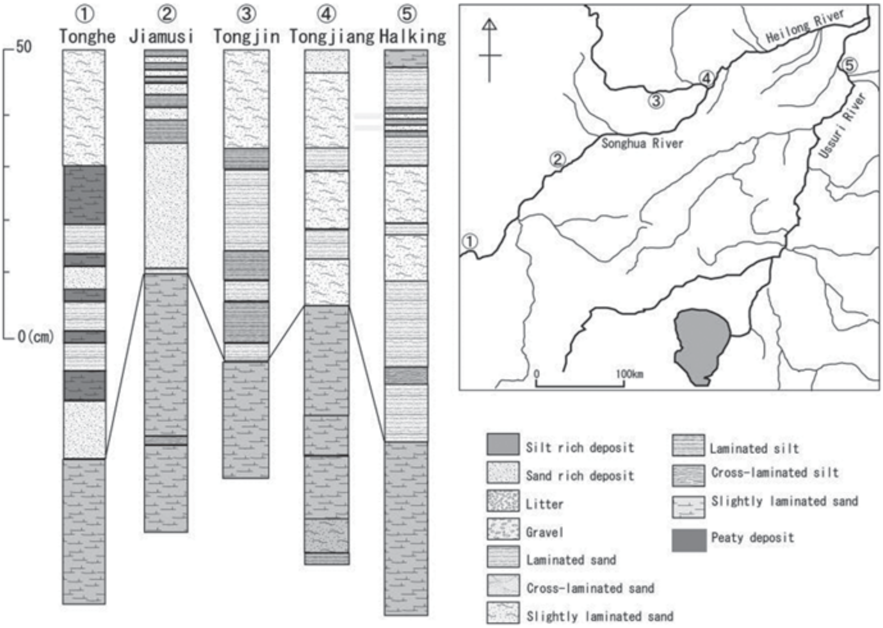


Fig. 4.6 Columnar sections of floodplain deposits on Sanjiang plain

Consequently, we investigated floodplain deposits along the Amur, Songhua, and Ussuri rivers, and branches of these rivers centered on the Sanjiang Plain. We selected the flat portion of the floodplain, which is flooded every year, as the focus of our research. We ignored topographic bulges such as natural levees. Floodplain deposits were sampled by making pits or extracting strata using a Geoslicer (Fukken Co., Ltd.). It was confirmed that the selected research point is a typical location for observing two or more surrounding points.

We found that sandy parts, which are coarser than in lower areas, were at the top of the floodplain deposits at most locations (Fig. 4.6). The thickness of this coarse-grained part varied from 30 to 70 cm, depending on location. At many other locations, we could distinguish the upper sandy part from the lower silt layer based on observations with the naked eye. We could also observe the development of stratification in all the profiles, especially in the upper sandy parts, where the development was remarkable. Therefore, these deposits are believed to have formed by numerous floods.

Figure 4.7 shows results of grain-size analysis of samples collected from the Tonjiang location on the Amur River. The figure shows vertical change in the fraction of sand particles coarser than 63 μm. The proportion of coarse sand increased considerably around 50 cm from the surface.

To clarify the age of such coarse grain sizes, we measured excess Cs-137 and Pb-210 contents. Figure 4.7 shows radionuclide profiles at Tonjiang, which indicate the presence of both radionuclides in the upper sand layer. Therefore, the measure-

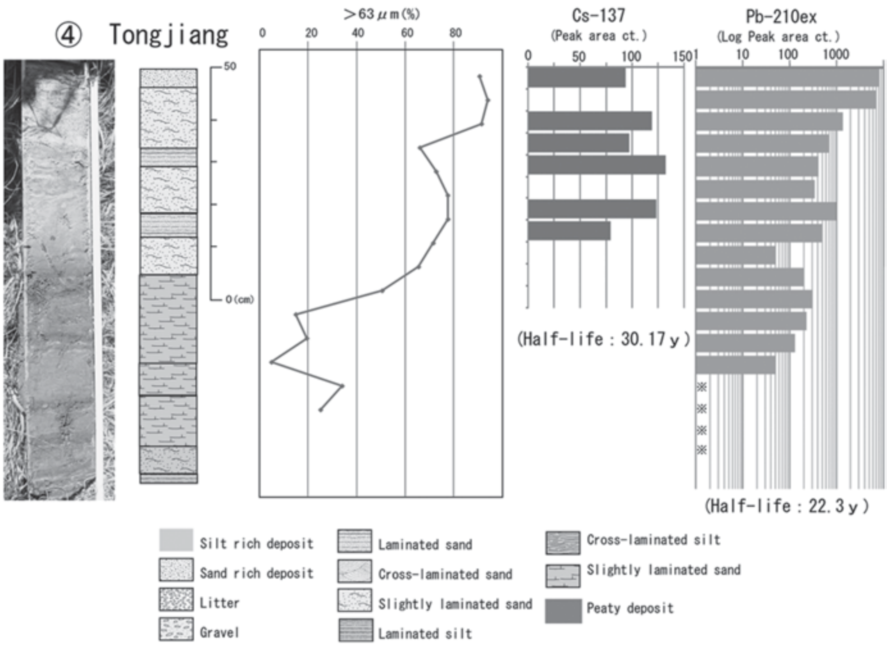


Fig. 4.7 Sediment strata of floodplain deposit at Tongjiang (*left*); profile of sand coarser than 63 μm content (*middle*); profile of excess Cs-137 and Pb-210 concentration (*right*)

ments confirmed that upper portions of the sediment were deposited during the last several decades.

We also investigated magnetic susceptibility profiles of continuous samples at several locations. Susceptibility increased near the surface in those profiles. It is generally known that the surface layer of stable soil has a high magnetic susceptibility (Evans and Heller 2003). Therefore, it is inferred from these results that material eroded from the surface soil of farmland on the hills was deposited on the floodplain.

4.5 Hydrologic Environmental Change and Deposit Coarsening

The reason for the coarsening of floodplain deposits is believed to be the development of farmland and deforestation, as mentioned previously. Active soil erosion on the bare ground could have increased the supply of coarse materials. Furthermore, the increase in surface flow could have augmented flood discharge, which would further increase coarse material outflow.

We investigated recent hydrologic data from the Amur River. Figure 4.8 shows the annual average discharge rate from 1895 to 2005 at Khabarovsk, which is in

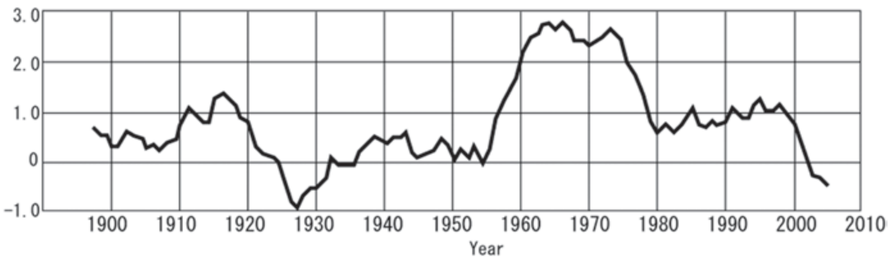


Fig. 4.8 Volume of Amur River flow at Khabarovsk hydrologic station, 1895–2001. (Novorotsky 2007)

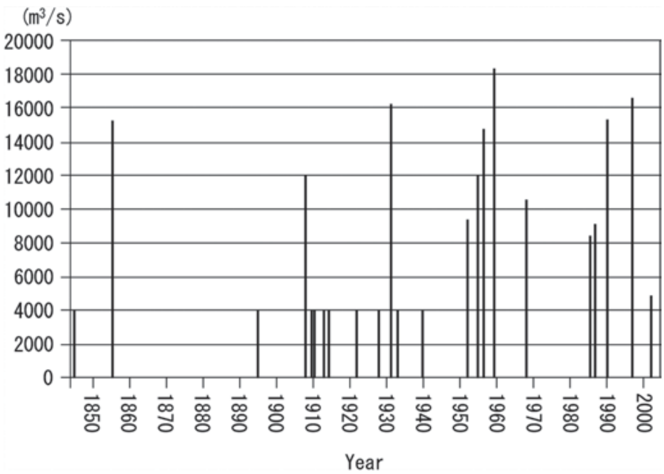


Fig. 4.9 Years of flooding and corresponding peak discharge data of Songhua River. Small-scale floods with no discharge data are shown as 4000 m^3/s

the lower part of the Sanjiang Plain in Russia (Novorotsky 2007). The graph shows a cyclic change and remarkable increase of discharge rate from the mid 1950s through the 1970s. However, regional precipitation in this period did not increase analogously (Bakalanov and Vornov 2010). Causes of the discharge rate increase could include land-cover changes, such as deforestation and conversion of wetlands to agricultural lands. The discharge rate decreased after the 1990s. The reason for this might be that new reclamation of farmland slowed; instead, bare ground was converted to farmland, which may have reduced flood discharge.

Figure 4.9 summarizes flood records of the Songhua River. Years of flooding and corresponding peak discharge data are shown. The records indicate that there has been an increase in large-scale floods since 1950. This is also considered to be influenced by land-cover change in the Songhua River Basin. Large-scale flooding of the river appears to be increasing, even after the 1990s. Hydrologic data suggest that floodplain deposit coarsening is caused by an increase in coarse-material supply, which in turn results from soil erosion of farmland in hilly areas and increased flood discharge.

In China, coarsening of floodplain sediment has been observed over a wide area. However, such systematic floodplain sediment coarsening has not been observed in Russia downstream from Khabarovsk. For this reason, it is possible that land-cover changes such as farmland exploitation are not progressing much in Russia relative to China. Moreover, the depositional environment may differ between the large-scale sedimentary basin of the Sanjiang Plain and its downstream portion. It is necessary to examine this further.

It is assumed that such hydrologic change and coarsening of floodplain deposits strongly affect the floodplain environment. A large portion of the present floodplain is occupied by wetlands. The environment of these wetlands is expected to change considerably if they are covered by highly permeable sand. For example, these wetlands could change to grasslands. As a result, the wetlands, an important source of nutrients such as iron, are disappearing. Also of concern is the possibility that ecosystems of the Amur River and Sea of Okhotsk will be seriously affected.

4.6 Conclusions

To reconstruct long-term hydrologic environmental change accompanying land-cover change in the Amur River Basin, we investigated floodplain sediment profiles around the Sanjiang Plain, which is on the middle reach of the Amur River.

1. From the results of field observation and analysis of remote sensing data, topography of the plain was classified into the present streambed, present floodplain, higher floodplain, fluvial terraces (lower, middle, and upper), and hilly area.
2. The relationship between the geomorphic surfaces and age data from previous studies suggests that the terrace gravel deposits formed during cold periods of glacial ages, and the peat layer developed during a relatively warm period. The formation period of the middle and lower terraces was estimated to be MIS 4 and MIS 2, respectively.
3. Profiles from the present floodplain confirmed coarsening of the upper part of floodplain deposits at many locations along the Amur, Songhua, and Ussuri rivers.
4. Measurement of excess Cs-137 and Pb-210 radionuclide contents confirmed that the upper coarse portions of sediment were deposited during the last several decades.
5. We presumed that the grain size coarsening of floodplain deposits resulted from an increase in peak discharge and coarse material supply, which were mainly caused by expansion of farmland in China.
6. Such recent coarsening of floodplain deposits could alter the environment of wetlands on the floodplain.

References

Bakalanov PA, Vornov BA (2010) Report on Amur-Okhotsk Project, vol 6, pp 315–325

Bao K, Zhao H, Xing W, Lu X, McLaughlin NB, Wang G (2011) Carbon accumulation in temperate wetlands of Sanjiang Plain, Northeast China. Soil Sci Soc Am J 75:2386–2397

Brooks AP, Brierley GJ (1997) Geomorphic responses of lower Bega River to catchment disturbance. Geomorphology 18:291–304

Evans EM, Heller F (2003) Environmental magnetism: principles and applications of enviromagnetics. Academic, San Diego, 299:1851–1926

Ganzey SS, Ermoshin VV, Mishina NV (2010) The landscape changes after 1930 using two kinds of land use maps (1930 and 2000). Report on Amur-Okhotsk Project, vol 6, pp 251–262

Haruyama S, Murooka M, Masuda Y, Yamagata K, Kondo A (2008) Landform and land use change of Heilongjiang province, North East China. Report on Amur-Okhotsk Project, vol 5, pp 139–150

Igarashi Y, Matsushita K, Takahashi H (1987) Peatland and its pollen profiles in the Sanjiang plain, Northeast China. Environ Sci 10:95–108 (Hokkaido University)

Lang A, Hönscheidt S (1999) Age and source of colluvial sediments at Vaihingen–Enz, Germany. Catena 38:89–107

Li C, Yi F, Zheng X, Li P, Ding S, Zhao K (1989) Conservation and utilization of marshes in Sanjiang plain, Heilongjiang Province—an opinion for developing Sanjiang region. In: Huang X (ed) Study of mires in China. Science Press, Beijing, pp 452–462

Murooka M , Haruyama S (2014) Impact assessment of land cover change on the middle reaches of the Amur River Basin. In: Haruyama S, Shiraiwa T (eds) Environmental change and the social response of the Amur River Basin. Springer

Neal C, Robson AJ, Wass P, Wade AJ, Ryland GP, Leach DV, Leeks GJL (1998) Major, minor, trace element and suspended sediment variations in the River Derwent. Sci Total Environ 210/211:163–172

Novorotsky PV (2007) The Amur's flow rate fluctuations for the last 110 years. Geogr Nat Resour 4:86–90

Song KS, Liu DW, Wang ZM, Khan S, Hafeez M, Mu JX (2007) A study on the wetland dynamic and its relation with cropland reclamation in Sanjiang plain, China. In: Proceedings of international congress on modeling and simulation, pp 2569–2575

Walling DE (1997) The response of sediment yield to environmental change. In: Walling DE, Probst JL (eds) Human impact on erosion and sedimentation. IAHS Press, Wallingford, pp 77–89

Yang Y (1988) An approach to problems of formation and development of marsh in the Sanjiang plain. In: Huang X (ed) Study of mires in China. Science Press, Beijing, pp 73–80

Zhao Y, Yu Z, Tang Y, Li H, Yang B, Li F, Zhao W, Sun J, Chen J, Li Q, Zhou A (2014) Peatland initiation and carbon accumulation in China over the last 50,000 years. Earth-Sci Rev 128:139–146

Chapter 5
Water Chemistry of the Middle Amur River

Seiya Nagao, Baixing Yan, Vladimir I. Kim, Vladimir P. Shesterkin, Svetlana I. Leveshina, Muneoki Yoh, Tomoyo Suzuki, Hiroki Kodama, Motoki Terashima, Osamu Seki and Alexey N. Makhinov

Abstract This chapter examines water chemistry in terms of iron, organic matter, and nutrients in river, drainage, and groundwater from the middle reaches of the Amur River, to ascertain the watershed environment of the Amur River Basin during 2005–2007. Nitrate-N concentration was 0.46 ± 0.38 mg/L for river water and 1.9 ± 5.0 mg/L for groundwater, corresponding respectively to 87 ± 11 % and 39 ± 42 % of total inorganic nitrogen. Dissolved iron concentrations were 0.10–1.08 mg/L

S. Nagao (✉)
Institute of Nature and Environmental Technology, Kanazawa University, Wake, Nomi, Ishikawa, 923-1224, Japan
e-mail: nagao37@staff.kanazawa-u.ac.jp

B. Yan
Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences, 3195 Weishan Road, Jilin, Changchun, 130012, China

V. I. Kim · V. P. Shesterkin · S. I. Leveshina · A. N. Makhinov
Institute of Water and Ecology Problems, Far Eastern Branch of Russian Academy of Science, 65 Kim Yu Chen St., Khabarovsk, 680000, Russia

M. Yoh
Institute of Agriculture, Tokyo University of Agriculture and Technology, 3-5-8 Saiwai-cho, Fuchu, Tokyo, 183-8509, Japan

T. Suzuki
Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa, Ishikawa, 920-1192, Japan

H. Kodama
Analytical Research Center for Experimental Science, Saga University, 1 Honjo, Saga, 840-8502, Japan

M. Terashima
Research Institute for Humanity and Nature, 457-4 Motoyama, Kita-ku, Kyoto, 603-8047, Japan

M. Terashima
Japan Atomic Energy Research Agency, Tokai, Ibaraki, Japan

O. Seki
Institute of Low Temperature Science, Hokkaido University, Kita-19, Nishi-8, Kita-ku, Sapporo, 060-0819, Japan

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_5

for river water and 0.39 ± 0.26 mg/L on average. A positive correlation was found between dissolved organic carbon (DOC) and dissolved iron concentrations in river water. However, the groundwater had average iron concentrations of 4.9 ± 3.1 mg/L and 4.3 ± 9.9 mg/L of DOC concentration, and there was no correlation between DOC and dissolved iron concentrations. The results indicate that wetland and forest areas are important in the export of dissolved iron and organic matter in the middle reaches of the Amur River. In the groundwater system, sources of dissolved iron and organic matter are independent for each underground environment, because of differences in geologic media, groundwater flow, and redox conditions.

Keywords Nutrients • Iron • Dissolved organic matter • River water • Groundwater

5.1 Introduction

Land use directly affects wildlife habitats and impacts local and global biodiversity. Human alteration of the landscape from natural vegetation to any other use engenders habitat loss, degradation, and fragmentation. A particular concern is deforestation, in which logging or burning is followed by conversion to agricultural or other land use. Climate change also affects land-use and land-cover changes.

The middle Amur River Basin includes floodplains of the Amur, Ussuri, and Songhua rivers. Extensive lowland wetlands on these floodplains are important in buffering floods, providing biogeochemical processes, and protecting ecosystem productivity. However, these areas are disturbed by various anthropogenic and natural impacts, such as forest fires, deforestation, and agricultural and industrial activities. Cultivated land area has been increasing along with rapid development of drainage channel systems and reclamation of marshes to upland and paddy fields over the past 50 years. Liu et al. (2004) reported that the area of wetlands on the Small Sanjiang Plain during 1950–2000 decreased by 53 %, but the share of agricultural lands increased from 10 to 55 % during that period. Kakizawa et al. (2010) pointed out that forest fires have strongly affected forest management and forest ecosystems in the Far East region of Russia.

Long-term differences in land use are well known to result in changes to soil organic matter quantity and composition (Guggenberger et al. 1994; Capriel 1997; Parfitt et al. 1997). Kalbitz et al. (1999) stated that long-term intensive land use increased aromatic structures within water-soluble fulvic acids that are caused by very strong peat decomposition, as compared with land use history that engenders lower peat decomposition (extensive land use or non-agricultural use). Wilson and Xenopoulos (2009) reported that changes in the character of dissolved organic matter are related to agricultural land use, nitrogen loading, and wetland loss. Land-use change and reclamation of agricultural fields in lowlands require drainage, which drastically changes the soil moisture regime. For example, the wetland area in the watershed of the Naoli River, a tributary of the Ussuri River on the Sanjiang Plain, decreased as much as 87 % during 1985–2000 (Liu and Li 2005). During this period, the dissolved iron concentration decreased sharply with wetland reclamation (Yan et al. 2008). Forest fires are a major human disturbance in the upstream mountains. These change the quantity and quality of organic matter in surface soil, thereby decreasing iron transport from burned forests to river streams. Dissolved iron concentrations in the surface waters of forest fire areas are lower than those of natural forest areas (Yoh et al. 2010; Shiraiwa 2012). Ascertaining the effects of land-use changes on water chemistry in soil, river, and underground layers demands basic information on chemical properties of water from the middle reaches of the Amur River.

This chapter describes water chemistry, especially dissolved iron and organic matter, of the middle Amur River, investigated from 2005 to 2007 under the international collaborative "Amur-Okhotsk Project" of the Research Institute for Humanity and Nature in Japan.

5.2 Study Area

The Amur River system, which originates from the Argun and Shilkan rivers, is one of the largest rivers in eastern Asia (Fig. 5.1a). The river system is 4444 km long and has seven major tributaries, the Shilkan, Argun, Zeya, Bureya, Songhua (Sungari), Ussuri and Amgun. The northern boundary of the Amur River Basin coincides with a mountain ridge and the southern border traverses a low floodplain. The watershed is 2.05×10^6 km^2, with 54% forest area and 20% agricultural land based on the compiled map "Modern Land-use in Amur River Watershed" (Ganzey et al. 2007). Territorial distributions of modern land-use types reflect both natural and climatic conditions. The major part of the upper and middle Amur area has low-mountain and middle-mountain relief with 400–500 m-deep valley (Makhinov 2005). Most of the river terrigenous discharge is formed in the middle Amur. In the lower Amur, eolian processes generate much of the detrital deposit formations. Annual rainfall ranges from 500 to 600 mm in the middle Amur area, which concentrates in July–September (Makhinov 2005). Mean annual water discharge was 8321 m^3/s (4167–12,600 m^3/s) at Khabarovsk during 1940–2009 (Nagao and Onishi 2013). Maximum water level and discharge are observed in the spring snowmelt season and during summer–autumn (July–October) from heavy rains. Significant water level rise from severe floods occurs once every 2 or 3 years (Ogi et al. 2001; Makhinov 2005).

The Amur River Basin land cover was 53.5% forest, 29.2% grass and dry land, and 6.9% wetland and others in 2000–2001 (Ganzey et al. 2010). Wetlands of the basin were mainly in low-lying areas of the Sanjiang Plain, along the Orshun and Argun rivers, and of plain along the Zeya and Bureya Rivers, and Lower Amur-Heilong, and Khanka lowlands. These wetlands have been converted to agricultural land, primarily paddy fields, during the last 50 years (Haruyama et al. 2007; Li et al. 2011). The watershed environment is related to water chemistry of the river water. Long-term monitoring of surface water chemistry has been done by the Far East Department of the Russian Federal Service For Hydrometeorology and Environmental Monitoring (ROSHYDROMET) since the 1960s. Figure 5.1b

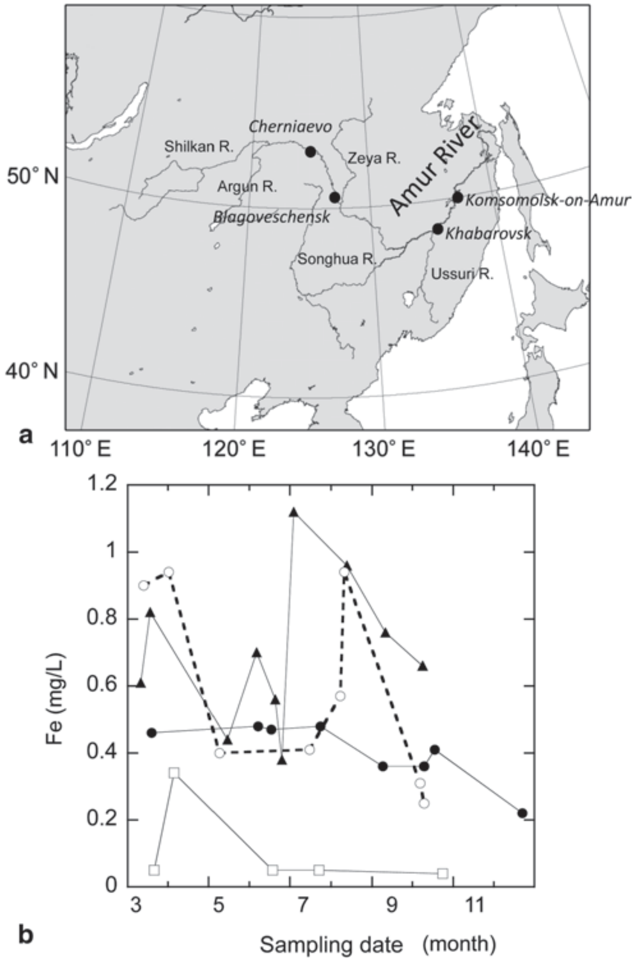


Fig. 5.1 Monitoring stations **a** and dissolved iron concentration **b** in river water from the *upper* (□ Cherniaevo), *middle* (● Blagoveschensk) and *lower* Amur River (▲ Khabarovsk, ○ Komsomolsk-on-Amur) in 2002 (modified from Nagao et al. 2010)

shows dissolved iron concentrations of river water, filtered with pore size ~0.7 µm, at Cherniaevo, Blagoveschensk, Khabarovsk, and Komsomolsk-on-Amur in 2002. The iron concentration was almost constant at Cherniaevo on the upper Amur with average 0.11 ± 0.13 mg/L, and at Blagoveschensk in the middle Amur with average 0.41 ± 0.09 mg/L. However, iron at Khabarovsk was 0.38–1.12 mg/L, with a maximum in summer. Similar variation was observed at Komsomolsk-on-Amur on the lower Amur River. Consequently, the middle and lower leaches of this river are regarded as sources of dissolved iron in river water (Nagao et al. 2010).

The average dissolved iron concentration in the middle Amur River was 0.30 ± 0.10 mg/L at Khabarovsk during 2006–2008 (Nagao et al. 2010), which is two orders of magnitude greater than that in major rivers throughout the world (Dai and Martin 1995). Dissolved iron flux from the Amur River to the Sea of Okhotsk has been estimated at $1.1 \pm 0.7 \times 10^{11}$ g/year (Onishi et al. 2008). The Sea of Okhotsk has high primary production, but it is not a high-nitrate and low-chlorophyll region because of sufficient iron transport from the Amur River. Therefore, this river is crucial to primary production in the Sea of Okhotsk (Shiraiwa 2010).

5.3 Materials and Methods

5.3.1 Sampling

Water samples were collected from rivers, channels, and wells in the middle reaches of the Amur River from 2005 to 2007 (Fig. 5.2). Well irrigation represents about 77% of total water resources at the State Farm on the Sanjiang Plain (Park and Sakashita 2010). Wells for irrigation and pumping water were chosen as groundwater sampling sites. Chemicophysical parameters were measured using a water quality checker (U-10; Horiba Ltd. and WQC-24; DKK–TOA Corp.).

5.3.2 Analysis

Nutrients such as NO_2^-, NO_3^-, NH_4^+, PO_4^{3-} and SiO_2 were measured using colorimetry after filtration with a 0.45 μm pore size filter. Dissolved organic carbon (DOC) concentration was also measured, using either an oxidative combustion-infrared method with a TOC analyzer (TOC-VCPH; Shimadzu Corp., Kyoto, Japan) or L.P. Krylova's method of dry burning in a quartz tube (Alekin et al. 1973) after filtration through Whatman GF/F filters. Water samples were filtered using a 0.45 μm pore size filter before and after addition of an HCl solution (Yoh et al. 2008). The former samples were used to measure the dissolved iron concentration, and the latter samples to measure acid-soluble iron. The iron concentration was measured by either ICP mass spectrometry (Elan DRC II; PerkinElmer Inc.) or an atomic absorption spectrophotometer (Z-8000; Hitachi Ltd.). The acid-soluble iron concentration represents the sum of dissolved and acid-leachable iron. Three-dimensional excitation emission matrix (3D-EEM) spectra were measured using a fluorescence spectrophotometer (F-4500; Hitachi Ltd.) with a 150 W ozone-free xenon lamp (Coble 1996; Nagao et al. 1997). Relative fluorescence intensity (RFI) of the samples was expressed in terms of quinine standard units (QSU); ten QSU corresponds to the fluorescence intensity of 10 μg/L quinine sulfate in 0.05 M sulfuric acid at an excitation wavelength (Ex.) of 350 nm and emission (Em.) wavelength of 455 nm. Size exclusion chromatograms were taken using high-performance size exclusion chromatography (HPSEC) with fluorescence detection (Nagao et al. 2001, 2003). Fluorescence was monitored at excitation wavelength 320 nm and emission wavelength 430 nm, corresponding to river fulvic acid.

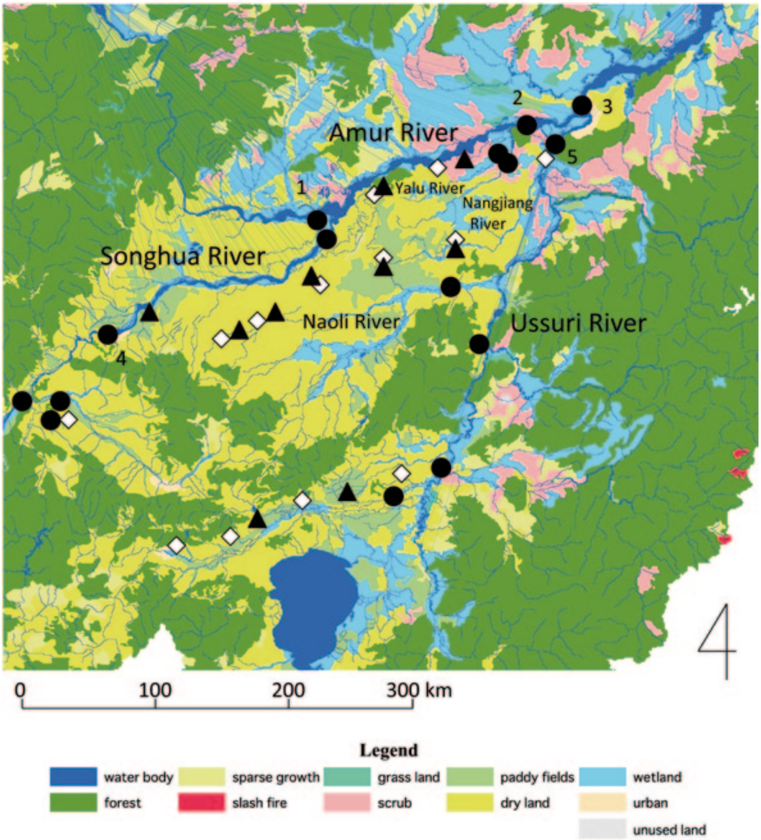


Fig. 5.2 Sampling locations in middle Amur River Basin in present study, conducted during 2005–2007. The land use map was referenced from Ermoshin et al. (2007). *Open* and *closed circles* respectively represent the sampling sites for river and drainage waters. *Closed triangles* represent groundwater sampling sites. Numbers on the map indicate sampling sites for investigation of chemical component transport, i.e. *1* Tongjiang, *2* Fuyuan, *3* Khabarovsk, *4* Jiamusi, and *5* Wusu

5.4 River Water Chemistry

5.4.1 Nutrients

Analysis results of inorganic nitrogen in river water from the middle reaches of the Amur River during 2005–2007 are presented in Table 5.1 and Fig. 5.3. Two sampling sites were on the Amur River and two were near the junction of the Amur, Songhua, and Ussuri rivers (Fig. 5.2). The main component of inorganic nitrogen is NO_3^--N, with concentrations of 10–1.00 mg/L in the Amur River, 0.03–0.66 mg/L in the Ussuri, and 0.26–1.18 mg/L in the Songhua. These values correspond to 12–99 % of total dissolved inorganic nitrogen (DIN). Lower percentages were observed at the Tongjiang site in January (12 %) and at Jiamusi in autumn (31 %),

Table 5.1 Water quality at the studied sites of the Amur River, Songuha River and Ussuri River during 2005–2007

River	Site	Date	Water Temp. (°C)	pH	EC (mS/m)	TOC	Total dissolved Fe	Acid soluble Fe (mg/L)	NH_4^+-N	NO_3^--N	NO_2^--N (μg/L)	PO_4^{3-}	SiO_2 (mg/L)
Amur	Tongjiang	2005/8/9	24.8	n.m.	7.2	8.15	0.33	1.05	n.d.	0.15	11.0	0.02	18.6
		2005/9/10	18.5	7.61	7.5	5.46	0.37	1.35	0.02	1	27.0	n.d.	14.8
		2006/5/20	10.0	n.m.	26.0	13.60	0.88	1.05	0.02	0.11	5.5	n.d.	6.9
		2006/7/29	21.8	7.01	6.0	5.92	0.28	0.62	0.04	0.1	14.0	n.d.	14.7
		2006/10/11	11.0	7.50	5.0	8.32	0.31	0.32	0.15	0.2	4.3	n.d.	8.6
		2007/1/12	0.0	7.30	6.0	10.32	0.32	0.33	1.82	0.26	2.8	n.m.	5.9
		2007/7/26	22.0	n.m.	16.0	9.49	0.18	0.45	0.03	0.51	171.0	0.05	6.5
		2007/8/28	17.4	n.m.	5.0	9.86	0.18	0.42	0.01	0.15	14.0	0.01	7.6
		2007/10/14	6.6	n.m.	6.0	8.65	0.27	0.32	0.03	0.17	6.2	n.d.	7.6
Amur	Fuyuan	2005/8/8	24.7	n.m.	12.3	9.68	0.27	0.38	n.d.	0.81	13.0	0.04	20.6
		2005/9/10	20.3	6.94	17.1	4.47	0.40	0.98	0.03	0.98	16.0	0.04	12.4
		2006/5/19	12.0	n.m.	8.0	10.80	1.08	1.29	n.d.	0.29	15.0	n.d.	2.4
		2006/7/28	23.0	7.66	7.0	5.10	0.42	0.63	0.04	0.45	8.3	n.d.	13.6
		2006/10/0	13.2	7.36	12.0	6.30	0.25	0.6	0.04	0.31	5.1	n.d.	4.4
		2007/1/13	4.0	7.00	17.0	7.70	0.24	0.32	0.65	0.71	9.4	n.m.	4.1
		2007/7/19	23.1	n.m.	7.0	8.00	0.26	0.76	0.05	0.13	n.d.	0.03	4.5
		2007/8/29	21.2	n.m.	9.0	9.60	0.44	0.52	n.d.	0.1	12.0	0.03	5.7
		2007/10/15	5.4	n.m.	10.0	13.10	0.30	0.59	0.03	0.18	5.3	0.01	6.2
Songuha	Jiamusi	2005/8/10	24.8	n.m.	15.0	4.82	0.73	1.12	n.d.	0.9	10.0	0.05	19.2
		2005/9/9	20.7	7.32	21.0	5.36	0.35	1.92	0.02	0.98	13.0	0.005	13.1
		2006/5/16	15.0	n.m.	17.0	5.58	1.20	2.77	n.d.	1.16	46.0	0.02	1.9

Table 5.1 (continued)

River	Site	Date	Water Temp. (°C)	pH	EC (mS/m)	TOC	Total dissolved Fe	Acid soluble Fe (mg/L)	NH_4^+-N	NO_3^--N	NO_2^--N (µg/L)	PO_4^{3-}	SiO_2 (mg/L)
		2006/7/26	23.0	7.60	12.0	6.29	0.46	0.62	0.02	1.18	11.0	n.d.	17.0
		2006/10/8	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
		2007/1/11	4.0	6.30	30.0	9.53	0.37	0.39	0.03	1.13	63.0	n.m.	1.9
		2007/7/23	23.7	n.m.	31.0	5.03	0.10	0.55	0.07	0.98	n.d.	0.03	0.8
		2007/8/27	22.1	n.m.	22.0	7.92	0.26	0.52	n.d.	0.79	20.0	0.01	1.2
		2007/10/13	11.4	n.m.	29.0	5.51	0.14	0.42	0.58	0.26	1.5	0.02	1.8
Ussuri	Wusu	2005/8/8	25.1	n.m.	11.6	5.62	0.44	0.62	0.005	0.66	8.0	0.03	21.5
	Raohe	2005/9/11	20.3	7.25	10.1	4.67	0.43	0.86	0.03	0.030	14.4	0.02	14.8
	Wusu	2006/5/18	13.0	n.m.	50.0	5.48	0.98	1.04	n.d.	0.15	7.4	0.01	6.4
	Wusu	2006/7/27	24.1	7.04	0.0	3.64	0.30	0.44	n.d.	0.03	6.6	n.d.	14.4
	Wusu	2006/10/9	14.1	7.76	5.0	4.27	0.32	0.37	0.04	0.09	3.2	n.d.	2.8
	Wusu	2007/1/14	4.0	7.60	15.0	0.33	0.21	0.34	0.12	0.41	6.1	n.d.	3.4
	Wusu	2007/7/24	22.3	n.m.	7.0	4.33	0.20	0.42	0.02	0.23	4.0	0.04	7.6
	Wusu	2007/8/29	19.6	n.m.	10.0	7.43	0.15	0.42	n.d.	0.4	14.6	0.03	8.5
	Wusu	2007/10/15	6.4	n.m.	9.0	6.50	0.34	0.37	0.04	0.27	5.3	0.02	10.1

Acid soluble Fe concentration indicates the sum of dissolved Fe and acid leachable Fe
n.d. <detection limit, *n.m.* no measurement

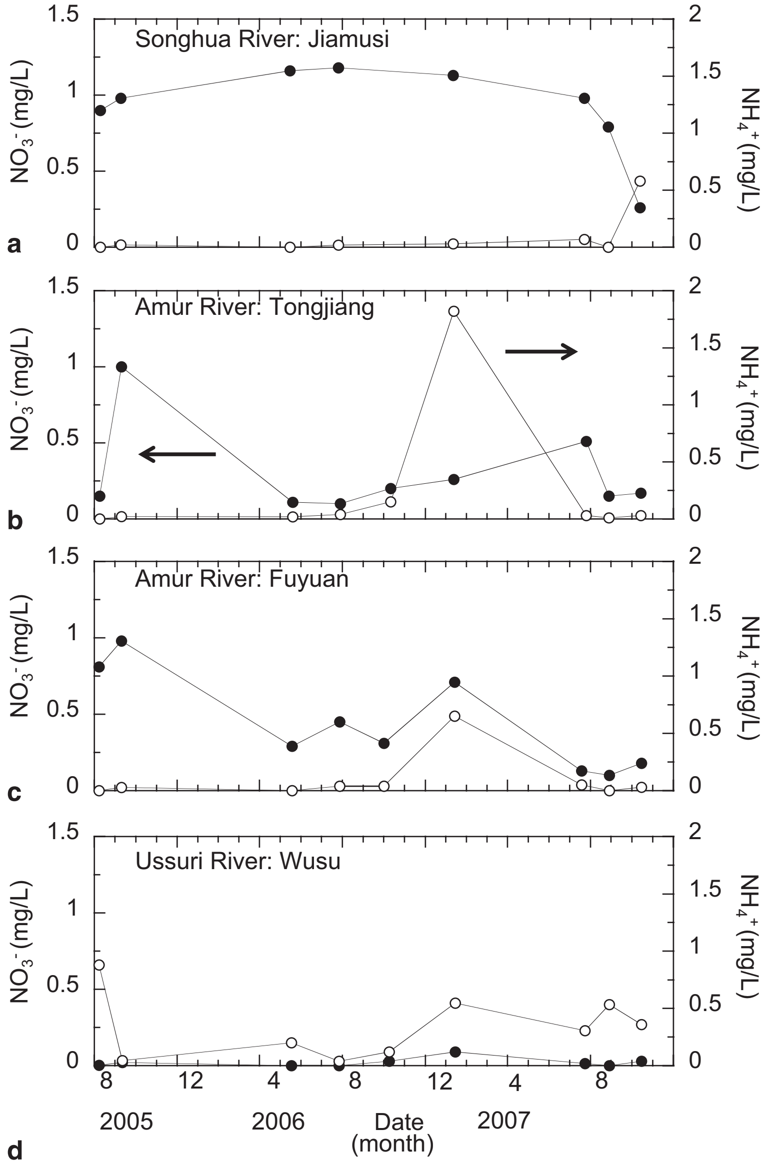


Fig. 5.3 Concentrations of NO_3^--N (●) and NH_4^+-N (○) in water samples from Songhua River at Jiamusi (**a**), Amur River at Tongjiang (**b**) and Fuyuan (**c**), and Ussuri River at Wusu (**d**)

because of a higher NH_4^+-N concentration of 0.58–1.82 mg/L. The average percentage of NO_3^--N to DIN is 85 ± 15 %, except for the above lower values at Tongjiang and Jiamusi Phosphate and silicate ion concentrations were, ~0.05 mg/L and 0.8–20.6 mg/L, respectively.

5.4.2 Iron

Dissolved iron concentrations in water from the Amur, Songhua, and Ussuri rivers in 2005–2007 are shown in Fig. 5.4. The iron concentration was 0.10–1.08 mg/L. The maximum concentration was observed at all stations in May 2006. However, a higher concentration ~0.4 mg/L was also found at the Fuyuan sampling station (site 2 in Fig. 5.2) at the middle Amur River in summer. The average iron concentration was 0.38 ± 0.23 mg/L for the Amur River, 0.40 ± 0.37 mg/L for the Songhua, and 0.37 ± 0.27 mg/L for the Ussuri. These values are similar to observation data at Khabarovsk and Bogorodskoe in 2006–2008 (Nagao 2008).

Yoh et al. (2008) reported that the dissolved iron concentration in pore water from Sanjiang Plain wetland soil at depths 0–50 cm was 0.5–5.0 mg/L during August 2005–2007. Yan et al. (2008) indicated that average dissolved iron concentration was 0.37 ± 0.03 mg/L for the main river waters and 1.12 ± 0.28 mg/L for marshy river waters on Sanjiang Plain during July–October 2007. These results are consistent with the variation of iron concentration from the upper to lower Amur River, as shown in Fig. 5.1. Dissolved iron is mainly from wetland and forest areas in the middle Amur River watershed.

The acid leachable iron concentration, which is estimated from the acid-soluble iron minus dissolved iron concentration, was from 0.01 to 0.98 mg/L (Fig. 5.4). This appears to be opposite the variation of dissolved iron concentration. The average value is 0.59 ± 0.62 mg/L for the Songhua site, 0.17 ± 0.13 mg/L for the Ussuri site, and 0.29 ± 0.26 mg/L for the Amur sites, which suggests that the acid leachable iron derived from riverine suspended solids is high in terms of its contribution from the Ussuri to lower Amur river.

5.4.3 DOC

The DOC concentration was 4.5–13.6 mg/L at the two Amur River sites, 4.8–9.5 mg/L at the Songhua site, and 0.33–6.5 mg/L at the Ussuri site (Fig. 5.5). The average DOC concentration was in the site order Ussuri < Songhua < Amur. The concentration and variation are greater than those of colorless river water (Nagao 2012). The brownish color of the water in the middle Amur River reflects the presence of humic substances, which are complex polymeric organic matter of widely varying molecular weight.

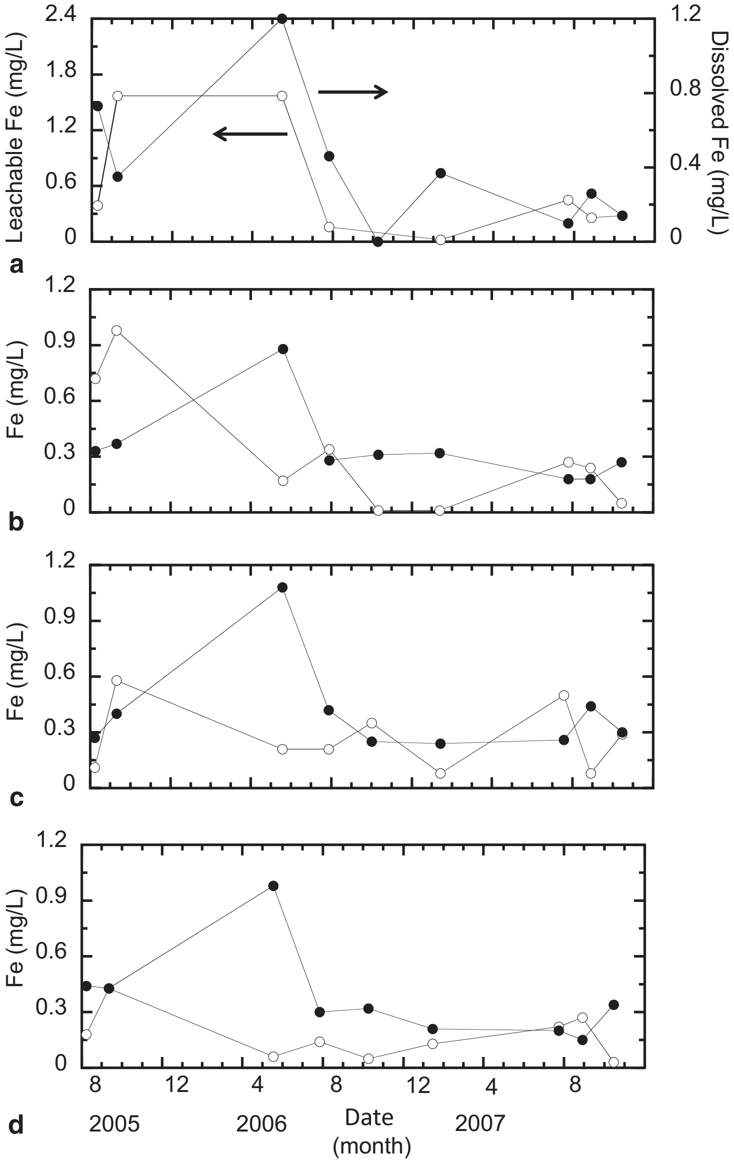


Fig. 5.4 Concentration of dissolved iron (●) and acid leachable iron (○) in water samples from the Songhua River at Jiamusi (**a**), Amur River at Tongjiang (**b**) and Fuyuan (**c**), and Ussuri River at Wusu (**d**)

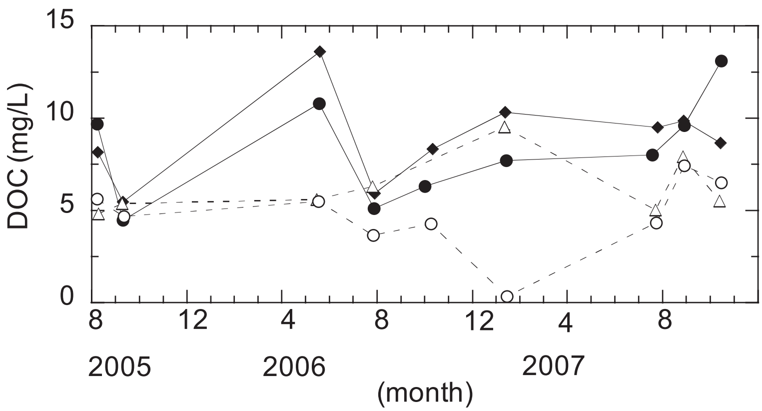


Fig. 5.5 DOC concentration in water from Songhua River (△ Jiamusi), Ussuri River (○ Wusu), and lower Amur River (♦ Tongjiang, ● Fuyuan)

5.4.4 Humic Substances

Figure 5.6 shows the fluorescence peak position detected in 3D-EEM spectra for water from the middle Amur River Basin. Data are referred from a report by Nagao et al. (2007a). River water from the Sanjiang Plain in August and September 2005 showed fluorescence peaks at Ex. 308–335 nm and Em. 403–430 nm. Rivers through wetlands showed higher peak positions at Ex. 320–335 nm/Em. 410–428 nm. Similar variations of fluorescence peak position have been found for fulvic acids isolated from river water in various environments (Nagao 2008).

The RFI of fulvic-like materials in water from the middle Amur River Basin was 26–192 QSU (Fig. 5.7). There was positive correlation ($r=0.70$) between DOC concentration and RFI. Rivers through wetlands had higher DOC and RFI values. These results reveal that the ratios of fulvic-like materials to dissolved organic matter were similar among these water samples.

Chromatograms monitored at Ex. 320 nm/Em. 430 nm contain four peaks, with elution volumes agreeing among the samples (Fig. 5.8). When the peak RFI is at longer excitation and emission wavelengths, the peak height ratio of peak 1/peak 2 increases, which indicates that fulvic-like materials with peaks at longer wavelengths in the 3D-EEM spectra reflect larger molecular size than those at shorter wavelengths.

Counter plots and chromatograms for water at Khabarovsk on the Amur River are shown in Fig. 5.9. The water samples have two broad maxima at Ex. 313–318 nm/Em. 427–433 nm and Ex. 338–356 nm/Em. 465–480 nm. Two fluorescent peaks have been reported for fulvic acid in the Suwannee River (Nagao et al. 2003), which rises in the Okefenokee Swamp of southern Georgia, and for river water flowing through Bekanbeushi wetland (Nagao 2008). Chromatograms monitored at

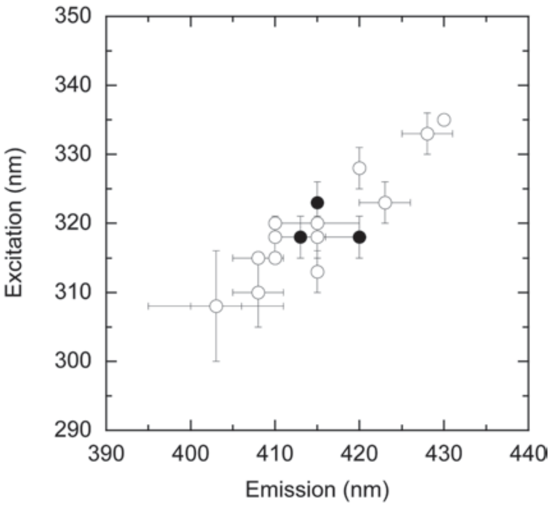


Fig. 5.6 Fluorescence peak position of fulvic-like materials in river water from Sanjiang plain in August and September 2005. *Closed circles* represent samples from the Amur, Songhua, and Ussuri rivers, as shown in Fig. 5.2. *Open circles* represent data for other sampling sites

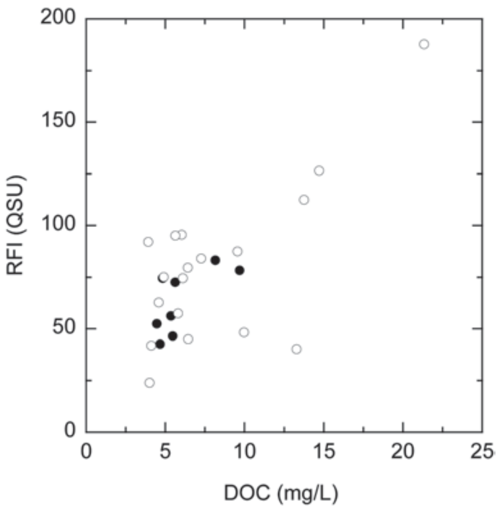


Fig. 5.7 RFI of fulvic-like materials as a function of DOC concentration in river water of Sanjiang plain in August and September 2005. Symbols are given in Fig. 5.6

Ex. 320 nm/Em. 430 nm contain four peaks, with elution volumes agreeing among the samples. The RFI of fulvic-like materials at Ex. 320 nm/Em. 430 nm was 77 QSU in 2005 and 101 QSU in 2007, but their peak position and chromatographic features were similar. These results indicate that features of fulvic-like materials in river water from the Sanjiang Plain depend on watershed environments such as wetlands, paddy fields, and upland fields.

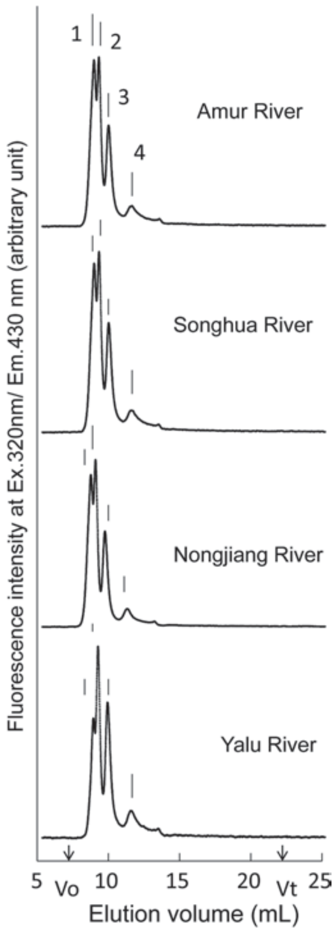


Fig. 5.8 Chromatograms of river water samples from Sanjiang plain in August 2005. Samples were measured using high-performance size exclusion chromatography with fluorescence detection of excitation wavelength 320 nm and emission wavelength 430 nm. Vo and Vt denote the void volume and total effective volume of the GPC column

5.5 Groundwater Chemistry

5.5.1 Na, Cl, and Nutrients

Groundwater chemistry in August and September 2005 on the Sanjiang Plain is represented in Fig. 5.2. Vertical distributions of basic parameters are shown in Fig. 5.10. Groundwater pH was measured for the samples in September 2005. The pH was 6.4–7.7 and had typical groundwater values. The concentration of Na and Cl were 6.7–31.6 mg/L and 0.2–42 mg/L, respectively. The DIN concentration was 0.003–3.2 mg/L for NO_3^--N, 0.5–26 µg/L for NO_2^--N, and ~1.4 mg/L for NH_4^+-N. The ratio of NH_4^+-N to total DIN concentration indicates three groups, a range 0–30% with average 10±13%, 55–80% with average 71±14%, and 90–100% with average 96±3%. The average value of all samples was 60±42% and the ammonium ion shows a dominant DIN component in the groundwater.

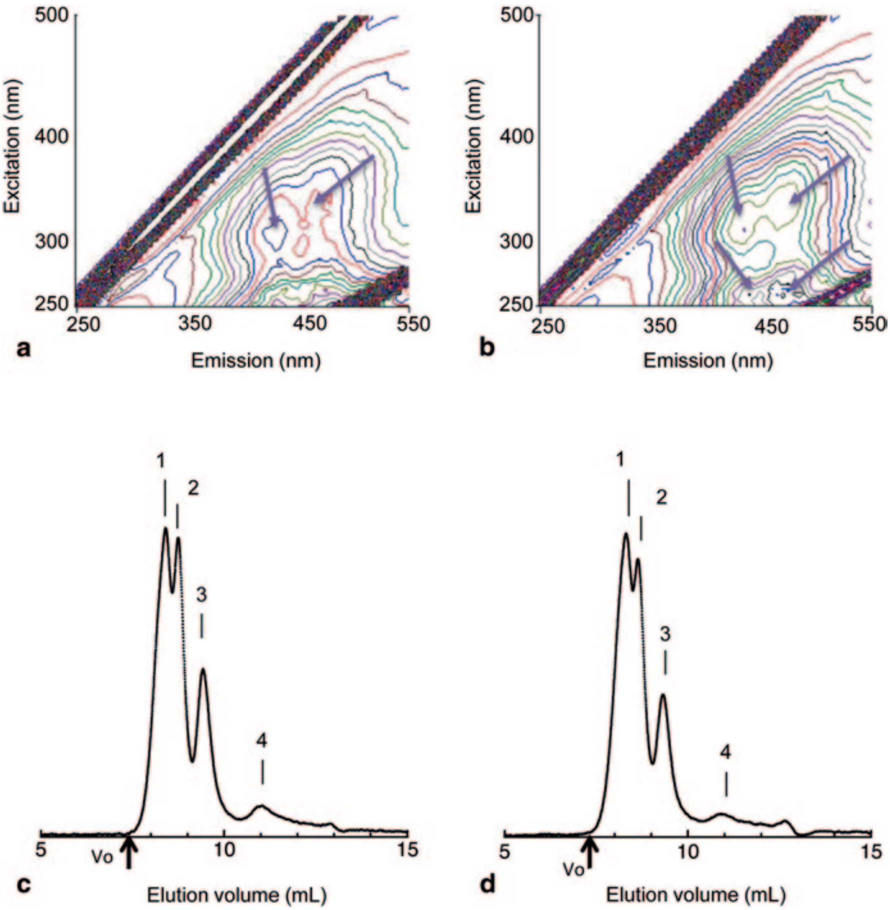


Fig. 5.9 Contour plots of excitation emission matrix spectra and chromatograms of Amur River water collected at Khabarovsk in August 2005 (**a**) and 2007 (**b**). Contour intervals are 5 QSU. *Arrows* indicate fluorescent peak positions. Chromatograms were determined using high-performance size exclusion chromatography with fluorescence detection at excitation wavelength 320 nm and emission wavelength 430 nm. Data referred from a report by Nagao et al. (2009a)

5.5.2 Iron and Dissolved Organic Matter

Figure 5.11 shows vertical distribution of DOC concentration, RFI of fulvic-like materials, and dissolved iron concentration in groundwater of the Sanjiang Plain. The DOC concentrations were 0.03–7.9 mg/L, except for two samples. The RFI of fulvic-like materials is shown for values at excitation 320 nm and emission 415 nm to elucidate the vertical variation pattern. Shallow groundwater from the ground surface to 40 m depth showed higher RFI than that of the deeper layer. However, dissolved iron concentration had a wide variation, from less than the detection limit to 41 mg/L. The average value was 4.9 ± 3.1 mg/L.

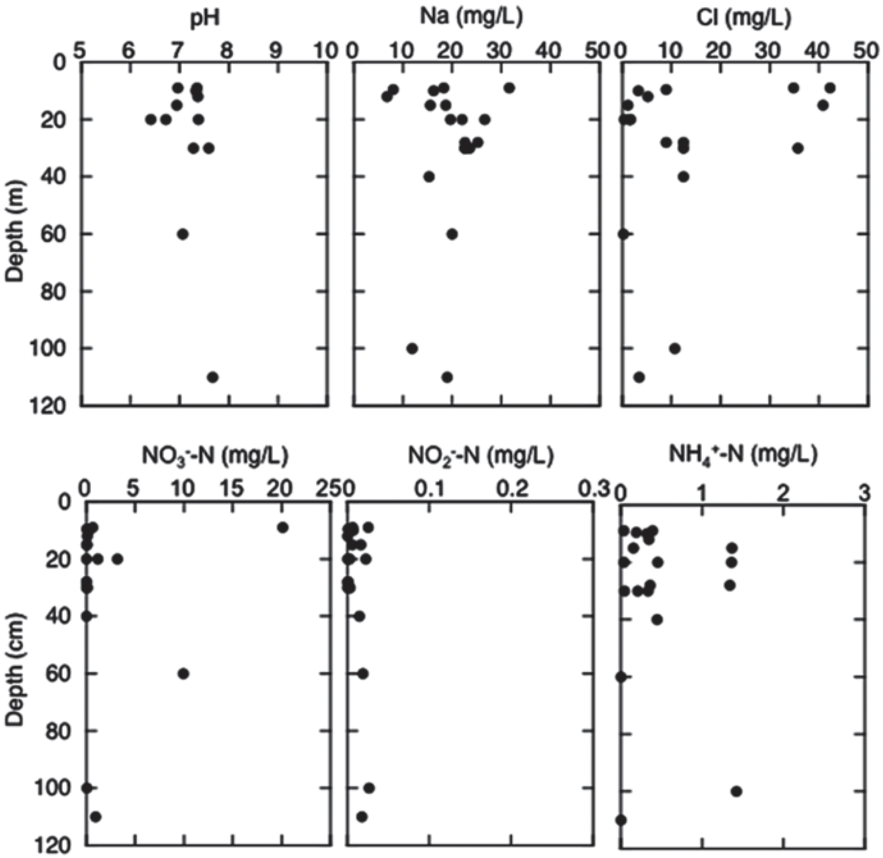


Fig. 5.10 pH, major ions (Na and Cl), and inorganic nitrogen components (NO_3^-, NO_2^-, NH_4^+) in groundwater from Sanjiang plain in August and September 2005

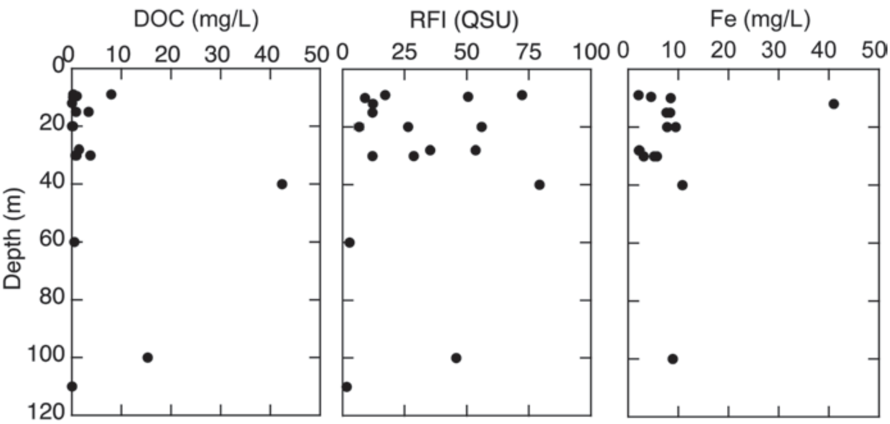


Fig. 5.11 Vertical profiles of DOC concentration, RFI of fulvic-like materials, and dissolved iron concentrations of groundwater from Sanjiang plain in August and September 2005

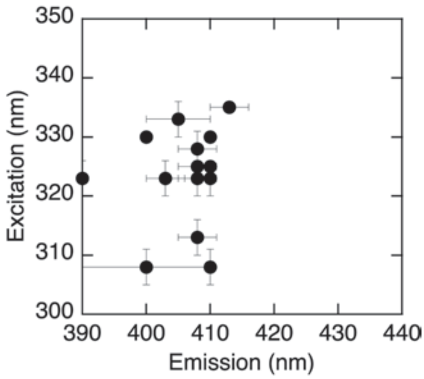


Fig. 5.12 Fluorescence peak positions of fulvic-like materials in groundwater from Sanjiang plain, collected in August and September 2005

5.5.3 Humic Substances

Fluorescence peak positions of fulvic-like materials in the shallow groundwater of Sanjiang Plain are portrayed in Fig. 5.12. Shallow groundwater at 9–110 m depths from the ground surface had fluorescence peaks at excitation wavelengths 308–335 nm and emission wavelengths 390–413 nm. The Tono area had similar peaks with fulvic-like materials in groundwater at 0–177 m depths from the surface (Nagao and Iwatsuki 2007; Nagao et al. 2009b).

Chromatograms of the typical groundwater are presented in Fig. 5.13. Fulvic-like materials in the groundwater had four peaks at elution volumes 8.5, 8.9, 9.6, and 11.3 mL. The apparent molecular weight at each peak corresponded to 11000, 9000, 7000, and 3500 Da, according to the calibration curve of molecular weight using polyethylene glycol standards (Nagao et al. 2003). The chromatograms were divisible into three types, based on peak height ratios for peaks 1–3. Types II and III are similar to those of surface river waters on the Sanjiang Plain (Fig. 5.13). However, type I indicates lower molecular size and weight than those of types II and III. A type I chromatogram was observed for deeper groundwater less than 10 m depth from the ground surface, with lower DOC concentration.

5.6 Behavior of Iron and Organic Matter

A positive correlation between iron and DOC concentrations has been reported for river water in the wetland (Tani et al. 2001), stream water (Ogawa 2003), and the Teshio River with wetland, paddy fields, and forest (Shibata et al. 2004) in Hokkaido, Japan. A similar correlation has been discovered in upstream forest areas (Yoh et al. 2010) and rivers through wetlands (Nagao et al. 2007b) within the Amur River Basin. Humic substances are 40–60 % of total dissolved organic matter in water and high complexation ability for dissolved iron (Aiken et al. 1985). Therefore, it is important to study characteristics of fulvic-like materials in natural water from rivers, drains, and underground layers.

Fig. 5.13 Typical chromatograms of groundwater of Sanjiang plain in August and September 2005, as determined by high-performance size exclusion chromatography with fluorescence detection at excitation wavelength 320 nm and emission wavelength 430 nm

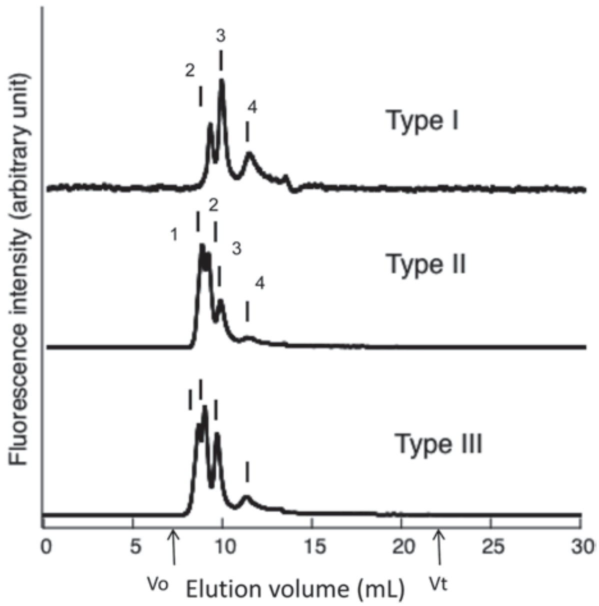


Figure 5.14 shows peak positions of fulvic-like materials in 3D-EEM spectra for river water, drainage water, and groundwater of the Sanjiang Plain in August and September 2005. The fluorescence maximum of fulvic-like materials in the river and drainage waters had excitation wavelengths 308–340 nm and emission wavelengths 400–435 nm. There was positive correlation of the fluorescent peak position between excitation and emission wavelengths. Groundwater had excitation wavelengths 308–335 nm and emission wavelengths 390–413 nm.

Size exclusion chromatograms show differences in chromatographic features (Fig. 5.13). These distinguish three groups, types I, II, and III. Differences in fluorescent peak position for fulvic-like materials may be related to their molecular size distribution. Nagao et al. (2009b) demonstrated that shallow groundwater in the Tono area had fluorescent peaks of fulvic-like materials at excitation wavelengths 285–325 nm and emission wavelengths 400–425 nm. The fulvic-like materials in groundwater from sedimentary rock layers had 12 nm higher peak positions at an excitation wavelength than those of a granitic formation. The fulvic-like materials are transported from different sources to groundwater and/or their characteristics vary during this transport because of sorption. Similar mechanisms might occur under shallow ground layers on the Sanjiang Plain.

The DOC concentration and RFI of fulvic-like materials had two correlations. That is, the ratio of RFI/DOC concentration indicates two groups, surface river water and drainage water, and groundwater (Fig. 5.15). The groups correspond to those of the fluorescent peak position (Fig. 5.14). The groundwater DOC concentration

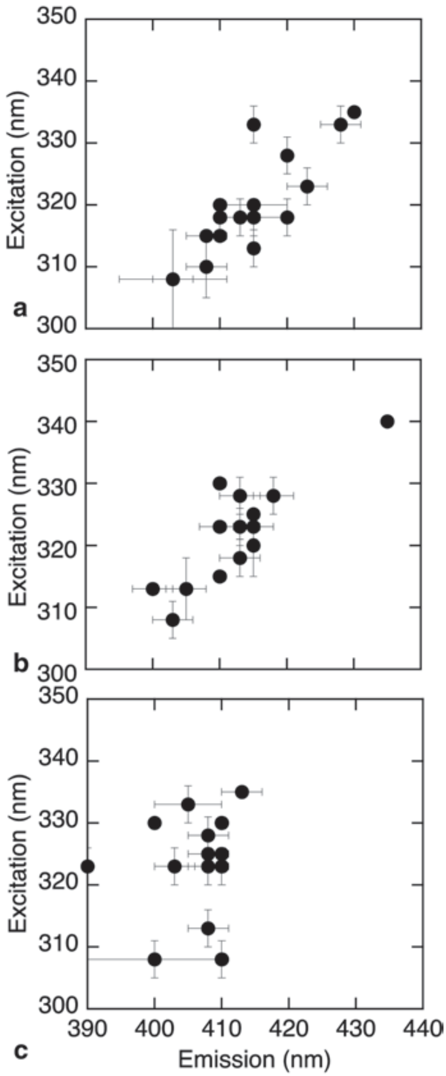


Fig. 5.14 Fluorescence peak position of fulvic-like materials in river water (**a**), drainage water (**b**), and groundwater (**c**) from Sanjiang plain in August and September 2005. Error bars represent deviation from average of duplicate measurements

had no correlation with dissolved iron concentration, although river and drainage water had a positive correlation (correlation factor $r=0.76$). These results suggest that in groundwater systems, the sources of dissolved iron and organic matter are independent, and dissolved iron concentration exceeds dissolved organic matter because of anoxic conditions. Results of chromatographic study show that the complexation capacity of groundwater fulvic-like materials varies in relation to their characteristics.

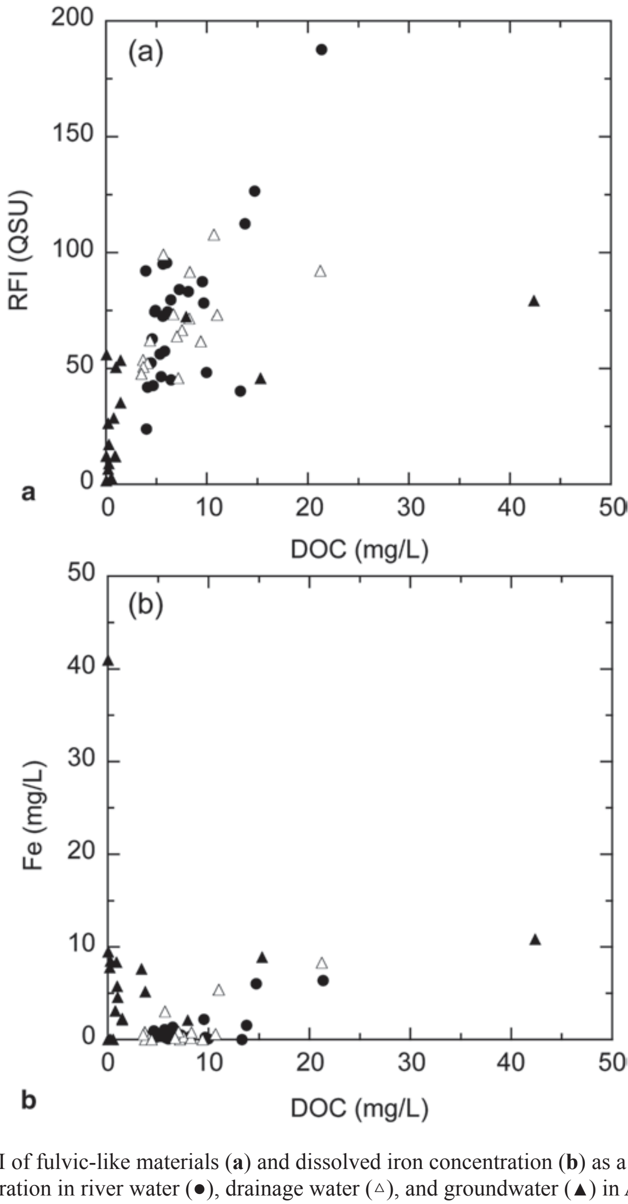


Fig. 5.15 RFI of fulvic-like materials (**a**) and dissolved iron concentration (**b**) as a function of DOC concentration in river water (●), drainage water (△), and groundwater (▲) in August and September 2005

5.7 Summary

The middle reaches of the Amur River have been developed through agricultural management and forest logging, and are being threatened by forest fires and global warming. Most river terrestrial discharge is from the middle Amur. Our findings indicate that the lower portion of the middle reaches and upper part of the lower Amur River with wetlands along the river are important sources of dissolved iron and organic matter, especially humic substances in the river water that sustain terrestrial and coastal ecosystems. Forest areas are also important sources of iron and organic matter in the middle Amur River Basin. Dissolved iron might be complexed with dissolved fulvic-like materials originating from forest areas and wetlands, because humic substances have high complex affinity for trace metal ions in aquatic environments. Therefore, we will continue to investigate water chemistry of the Amur River system to elucidate the effects of land-use and land-cover changes on water chemistry, and to detect very weakly changing signatures of human and natural impacts on the aquatic environment.

Acknowledgement We wish to thank S. Hirakawa, N. Yoshida, S. Itoh and Y. Nakamura for helping with spectroscopic and chromatographic analyses. We also thank the captain and crew of R/V *Ladoga* and Dr. M. Kawahigashi of Tokyo Metropolitan University for the sampling during the Amur River expedition. This study was conducted under the Amur-Okhotsk Project 2005–2009 (project leader Dr. T. Shiraiwa) of the Research Institute for Humanity and Nature.

References

Aiken GR, McKnight DM, Wershaw RL, MacCarthy P (1985) Humic substances in soil, sediment and water. Wiley, New York

Alekin OA, Semenov AD, Skopintsev BA (1973) Handbook for surface water chemical analysis. Hydrometizdat, Leningrad, pp 162–177 (in Russian)

Capriel P (1997) Hydrophobicity of organic matter in arable soils: influence of management. Eur J Soil Sci 48:457–462

Coble PG (1996) Characterization of marine and terrestrial dissolved organic matter in seawater using excitation emission matrix spectroscopy. Mar Chem 51:325–346

Dai M, Martin JM (1995) First data on trace metal level and behavior in two major Arctic river–estuarine systems (Ob and Yenisey) and in the adjacent Kara Sea. Earth Planet Sci Lett 131:127–141

Ermoshin VV, Ganzey SS, Murzin AV, Mishina NV, Kudryavitzeva EP (2007) Creation of GIS for Amur River Basin: the basic geographical information. In: Report on Amur–Okhotsk Project No. 4, Research Institute for Humanity and Nature, pp 151–159

Ganzey SS, Ermoshin VV, Mishina NV, Shiraiwa T (2007) The basic features of land-use in Amur River watershed. In: Report on Amur–Okhotsk Project No. 4, Research Institute for Humanity and Nature, pp 139–150

Ganzey SS, Ermoshin VV, Mishina NV (2010) The landscape changes after 1930 using two kinds of land use map (1930 and 2000). In: Report on Amur–Okhotsk Project No. 6. Research Institute for Humanity and Nature, pp 251–263

Guggenberger G, Christensen BT, Zech W (1994) Land-use effects on the composition of organic matter in particle size separates of soil: I. Lignin and carbohydrate signature. Eur J Soil Sci 45:449–458

Haruyama S, Masuda Y, Kondoh A, Murooka M, Yamagata K (2007) Evaluation of land-cover change in Amur basin using NDVI derived from NOAA/AVHRR PAL Dataset. In: Report on Amur–Okhotsk Project, No. 4, Research Institute for Humanity and Nature, pp 129–138

Kakizawa H, Park H, Sakashita A, Yamane M (2010) Analyses on underlying causes behind land-use/land-cover changes. In: Report on Amur–Okhotsk Project No. 6, Research Institute for Humanity and Nature, pp 63–73

Kalbitz K, Geyer W, Geyer S (1999) Spectroscopic properties of dissolved humic substances—a reflection of land use history in a fen area. Biogeochemistry 47:219–238
Li H, Kondoh A, Shen Y (2011) Interannual changes in the distribution of paddy field in Sanjiang plain, Northeast China by satellite remote sensing. J Jpn Soc Hydrol Water Resour 24:85–93
Liu HY, Li ZF (2005) Hydrological regime changing process and analysis of its influencing factors in a typical wetland of the Sanjiang plain. J Nat Resour 20:493–501 (in Chinese)
Liu H, Zhang Sh, Li Z, Lu X, Yang Q (2004) Impact on wetlands of large-scale land-use changes by agriculture development: the small Sanjiang plain, China. Ambio 33:306–310
Makhinov AN (2005) Amur terrigene and chemical discharge formation. In: Report on Amur-Okhotsk Project, No. 3, Research Institute for Humanity and Nature, pp 61–65
Nagao S (2008) Humic substances in natural waters. In: Ishiwatari R, Yonebayashi K, Miyajima T (eds) Humic substances in environment: their characteristics and research methods. Sankyo-Shuppan, Tokyo (in Japanese)
Nagao S (2012) Characteristics of DOM and its transport and association with bioavailable trace metals in river systems. In: Japanese Society of Soil Science and Plant Nutrition (ed) Dynamics and function of dissolved organic matter—connecting soil to sea through river. Hakuyusha Co. Ltd., Tokyo (in Japanese)
Nagao S, Iwatsuki T (2007) Convenient characterization of humic substances in deep groundwaters by three-dimensional excitation emission matrix spectroscopy. Bunseki Kagaku 56:143–150 (in Japanese)
Nagao S, Onishi T (2013) Amur River. In: Takahashi T, Takara K, Nomura K, Haruyama S (eds) World river dictionary. Maruzen Publishing Co. Ltd., Tokyo (in Japanese)
Nagao S, Suzuki Y, Nakaguchi Y, Senoo M, Hiraki K (1997) Direct measurement of the fluorescence characteristics of aquatic humic substances by a three-dimensional fluorescence spectrophotometer. Bunseki Kagaku 46:335–342 (in Japanese)
Nagao S, Matsunaga T, Suzuki Y, Hiraki K (2001) Convenient method of UV-absorbing organic materials in river waters by high-performance gel permeation chromatography. Chikyukagaku 35:107–120 (in Japanese)
Nagao S, Matsunaga T, Suzuki Y, Ueno T, Amano H (2003) Characteristics of humic substances in the Kuji River waters as determined by high-performance size exclusion chromatography with fluorescence detection. Water Res 37:4159–4170
Nagao S, Itoh S, Terashima M, Yoh M, Yan B, Zhang B, Onishi T (2007a) Fluorescent properties of dissolved humic substances in the Sanjiang plain river waters. J Jpn Soc Water Environ 30:629–635 (in Japanese)
Nagao S, Terashima M, Kodama H, Kim VI, Shesterkin PV, Makhinov AN (2007b) Migration behavior of Fe in the Amur River Basin. In: Report on Amur-Okhotsk Project, No. 4, Research Institute for Humanity and Nature, pp 37–48
Nagao S, Suzuki T, Kawahigashi M, Kodama H, Onishi T, Yoh M, Shiraiwa T, Shesterkin VP, Kim VI, Leveshina SI, Makhinov AN, Yan B, Zhang B (2009a) Characteristics of fluorescent dissolved organic matter in the middle and lower Amur River. In: Proceedings of the International Conference land cover and land use change in Northeast Asia: problems of sustainable nature management, pp 107–111
Nagao S, Seki Y, Watanabe Y (2009b) Fluorescent characteristics of dissolved organic materials in groundwaters from tertiary rocks near uranium showings. J Nucl Fuel Cycle and Environ 15:69–76 (in Japanese)
Nagao S, Terashima M, Seki O, Takata H, Kawahigashi M, Kodama H, Kim VI, Shesterkin VP, Leveshina S, Makhinov AN (2010) Biogeochemical behavior of iron in the lower Amur River and Amur–Liman. In: Report on Amur–Okhotsk Project No. 6, Research Institute for Humanity and Nature, pp 41–50
Ogawa A (2003) Spatial variability of stream water chemistry in a forested watershed in Hokkaido, Japan, Master Thesis of College of Environmental Science and Forestry, State University of New York
Ogi M, Tachibana Y, Nishio F, Danchenkov MA (2001) Does the fresh water supply from the Amur River flowing into the Sea of Okhotsk affect sea ice formation? J Metrol Soc Japan 79:123–129

Onishi T, Shibata H, Nagao S, Park H, Yoh M, Shamov VV (2008) Long-term trend of dissolved iron concentration and hydrological model in cooperating dissolved iron production mechanism of the Amur River Basin. In: Report on Amur-Okhotsk Project No. 4, Research Institute for Humanity and Nature, pp 199–207

Parfitt RL, Theng BKG, Whitton JS, Shepherd TG (1997) Effects of clay minerals and land use on organic matter pools. Geoderma 75:1–12

Park H, Sakashita A (2010) Characteristics of agricultural development on Sanjiang plain. In: Report on Amur–Ohkotsk Project No. 6. Research Institute for Humanity and Nature, pp 283–289

Shibata H, Konohira E, Satoh F, Sasa K (2004) Export of dissolved iron and the related solutes from terrestrial to stream ecosystems in northern part of Hokkaido, northern Japan. In: Report on Amur–Okhotsk Project No. 2, Research Institute for Humanity and Nature, pp 87–92

Shiraiwa T (2010) Final report of the Amur Okhotsk Project 2005–2009. In: Report on Amur–Okhotsk Project No. 6, Research Institute for Humanity and Nature, pp 3–19

Shiraiwa T (2012) Amur River and Sea of Okhotsk Sea and Oyashio. In: Field Science Education and Research Center (ed) River connecting the forest and sea. Kyoto University Press, Kyoto (in Japanese)

Tani M, Kondo R, Tsutsuki K (2001) Dissolved organic matter and its interaction with dissolved iron in peat pore waters. J Sci Soil Manure, Japan 72:348–356 (in Japanese)

Wilson HF, Xenopoulos MA (2009) Effects of agricultural land use on the composition of fluvial dissolved organic matter. Nat Geosci 2:37–41

Yan B, Zhang B, Pan X, Yoh M (2008) Effects of LUCC on concentration of iron in aquatic systems and flux of various forms of iron in main rivers in the Sanjiang plain. In: Report on Amur–Okhotsk Project No. 5, Research Institute for Humanity and Nature, pp 59–71

Yoh M, Guo Y, Wang D, Yan B (2008) Biogeochemical behavior of dissolved iron in Sanjiang plain, China: discharge, chemical forms, and year-to-year variation. In: Report on Amur–Okhotsk Project No. 5, Research Institute for Humanity and Nature, pp 53–57

Yoh M, Shibata H, Onishi T, Kawahigashi M, Guo Y, Ohji B, Yamagata K, Shamov VV, Leveshina SI, Novorotskaya A, Matyushkia L, Yan B, Wang D, Pan X, Zhang B, Chen X, Huang B, Chi G, Shi Y, Shi F, Xu X, Zhang K, Cai T, Sheng H (2010) Iron dynamics in terrestrial ecosystems in the Amur River Basin. In: Report on Amur–Okhotsk Project No. 6, Research Institute for Humanity and Nature, pp 51–62

Chapter 6
Droughts in North Eurasia and Climate Warming: Regional Changes and Consequences

Valeria V. Popova, Alexandr N. Zolotokrylin, Elena A. Cherenkova and Tatyana B. Titkova

Abstract Analysis of the climatic frequency of atmospheric drought in North Eurasia is presented. Its mean geographic distribution, changes during global warming, and specific features during a 2010 heat wave are given. Various indices of drought conditions are compared and discussed. The 2010 event was extreme, although other indices place it among other twentieth-century events. A satellite-based index of drought conditions is proposed, based on remotely sensed albedo, surface temperature, and NDVI. This permits analysis of detailed spatiotemporal structure of the 2010 drought dynamics. Large-scale atmospheric mechanisms of drought evolution in North Eurasia are explored. Detailed statistical analysis demonstrates that since the mid 1980s, the frequency of positive temperature anomalies during summer in that region has increased, and the major cause is a decrease of the West Pacific circulation index, reflecting a weakening of zonal atmospheric flows over the subcontinent. There was a statistical relationship in May and April with July air temperature on the East European Plain each year, allowing prediction of regional droughts in certain cases.

Keywords Droughts • Climate warning • North Eurasia • Regional changes

6.1 Introduction

In continental regions of the world, droughts are one of the greatest potential threats to nature and society. Droughts result in low harvests, forest fires, decrease of available water resources, among other outcomes. Heat waves, which normally accompany droughts, cause health problems and numerous deaths. Many non-coastal (and some coastal) regions of North Eurasia are prone to drought, because precipitation there is generally light and there are high temperatures nearly every summer. Drought in Russia and adjacent countries has historically been regarded as one of the worst calamities in the region, causing hunger, disease, and other negative

Andrey B. Shmakin has been deceased.

V. V. Popova (✉) · A. N. Zolotokrylin · E. A. Cherenkova · T. B. Titkova
Institute of Geography, Russian Academy of Sciences,
Staromonetny St. 29, 119017 Moscow, Russia
e-mail: valeria_popova@mail.ru

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_6

effects (Bedritsky 2008). This is especially true for the continental plains of North Eurasia, where other natural disasters are comparatively rare.

The Great Russian Drought of 2010 and other drought events in North Eurasia have raised numerous questions about the geography, statistics, mechanisms, and impacts of droughts on the subcontinent, their relationships to climate change, and others (Barriopedro et al. 2011; Blunden et al. 2011; Grumm 2011; Jiang et al. 2006; Lau and Kim 2012). This study provides statistical data on atmospheric and soil droughts in the region (Russia and adjacent countries), explains major atmospheric circulation regimes affecting these droughts, and reviews contemporary changes of drought intensity and distribution.

6.2 Data

For statistical studies of drought over North Eurasia, data from the Russian Institute of Hydrometeorological Information (RIHMI) and other sources were used. The main RIHMI dataset consists of daily records of air temperature and precipitation at 600 stations throughout the territory of the former USSR, including 526 stations in Russia (http://www.meteo.ru/climate/sp_clim.php). Time series in the archive begin from the start of observation at each station between 1891 and 1960, and end in autumn 2010 in Russia; for other former Soviet countries, the records end between 1991 and 2006. Additional meteorological data were obtained from a National Oceanic and Atmospheric Administration (NOAA) website (http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html) to cover gaps in ex-USSR territory and to provide data from Finland and other neighboring countries. Using daily meteorological records, certain characteristics were calculated. These included mean monthly air temperature, monthly precipitation sum, maximum annual temperature, number of days of atmospheric drought and its continuous duration, and drought indices based on monthly parameters. Atmospheric drought criteria were chosen according to Vasiliev and Belinskiy (2001): daily precipitation less than 5 mm, combined with maximum daily air temperature greater than 25 °C at latitudes higher than 52 °N and longitudes less than 50 °E, or latitudes higher than 55 °N and longitudes greater than 50 °E; or daily precipitation less than 5 mm, combined with maximum daily air temperature warmer than 30 °C in the rest of North Eurasia.

Data on the characteristics of large-scale atmospheric circulation were from NOAA (http://www.cpc.ncep.noaa.gov/data/teledoc). NOAA has prepared monthly mean values of several indices, characterizing the major circulation mechanisms of the Northern Hemisphere extratropics. The indices are obtained by the empirical orthogonal function method applied to variations of the geopotential field at 700 hPa level, so they are objective and statistically independent from each other (Barnston and Livezey 1987). As major components of pressure field variations above Eurasia in the warm half of the year, the following circulation patterns can be distinguished: North Atlantic Oscillation (NAO), Pacific—North American (PNA), Polar-Eurasia (POL), West Pacific (WP), East Atlantic (EA), Scandinavian (SCAND), and East

Atlantic—West Russia (EAWR). Mean July air temperature calculated at each station was re-interpolated onto a regular grid by the kriging method. These data obtained for each year and their relationships to atmospheric circulation indices were studied using multi-dimensional statistics (principal component analysis, stepwise multiple regression). As has been demonstrated (Popova 2009), the greater part of the East European Plain can be considered homogeneous with regard to mean July air temperature variations. Thus, for this region, one can obtain statistically significant relationships between July air temperature and the circulation indices. Data of mean July geopotential height at the 500 hPa level in a region delimited by 40–75 °N and 20–100 °E were also used for analysis of circulation mechanisms.

Moreover, satellite data of surface temperature and albedo, as well as a vegetation index, were used for studies of the spatiotemporal behavior of the 2010 drought. Details on these data are given subsequently.

6.3 Drought Distribution over Northern Eurasia and Frequency Change in the Last Decades

The mean frequency of atmospheric drought for 1951–1980 in North Eurasia during July, according to the aforementioned criteria, is shown in Fig. 6.1a. The major curve of isolines near the Ural Mountains is caused by the criterion in which 55 °E longitude is used as a parameter, so it may be regarded as an artifact. The highest frequency of atmospheric drought is in Central Asia, east of the Caspian Sea; drought here normally lasts for the entire month of July. In the northwest, north and northeast of the subcontinent, the number of drought days is negligible, owing to either sufficient precipitation or insufficiently high temperature. The same situation is seen near the Black Sea and on the Pacific coast. These regions are warm in summer, but normally precipitation is abundant, thereby limiting the number of drought days to just a few per month. More than 15 days of atmospheric drought in July are found in some parts of South Siberia, as well as in large regions north of Central Asia. A major Russian agricultural region in the North Caucasus, between the Sea of Azov and Caspian Sea, usually has more than 10 days of drought.

During the recent global warming period (since 1989), the number of atmospheric drought days has changed in a limited number of regions (Fig. 6.1b). Large regions with significant changes, southwest of the Black Sea and in Central Asia near 100 °E, are actually beyond the territory covered by the observed data, so these should be ignored. The only sizeable region with a significant increase in July atmospheric drought frequency is northeastern Siberia, but the total number of droughts there remains low. Other regions of increased atmospheric drought frequency are small, so their accumulated effect at subcontinent scale is not strong. However, almost nowhere is there a decrease in the number of atmospheric drought days.

When analyzing the change of atmospheric drought frequency, one could examine the major influences, i.e., temperature and precipitation. Air temperature is increasing over most of North Eurasia in summer, including July (Fig. 6.1c). Summer

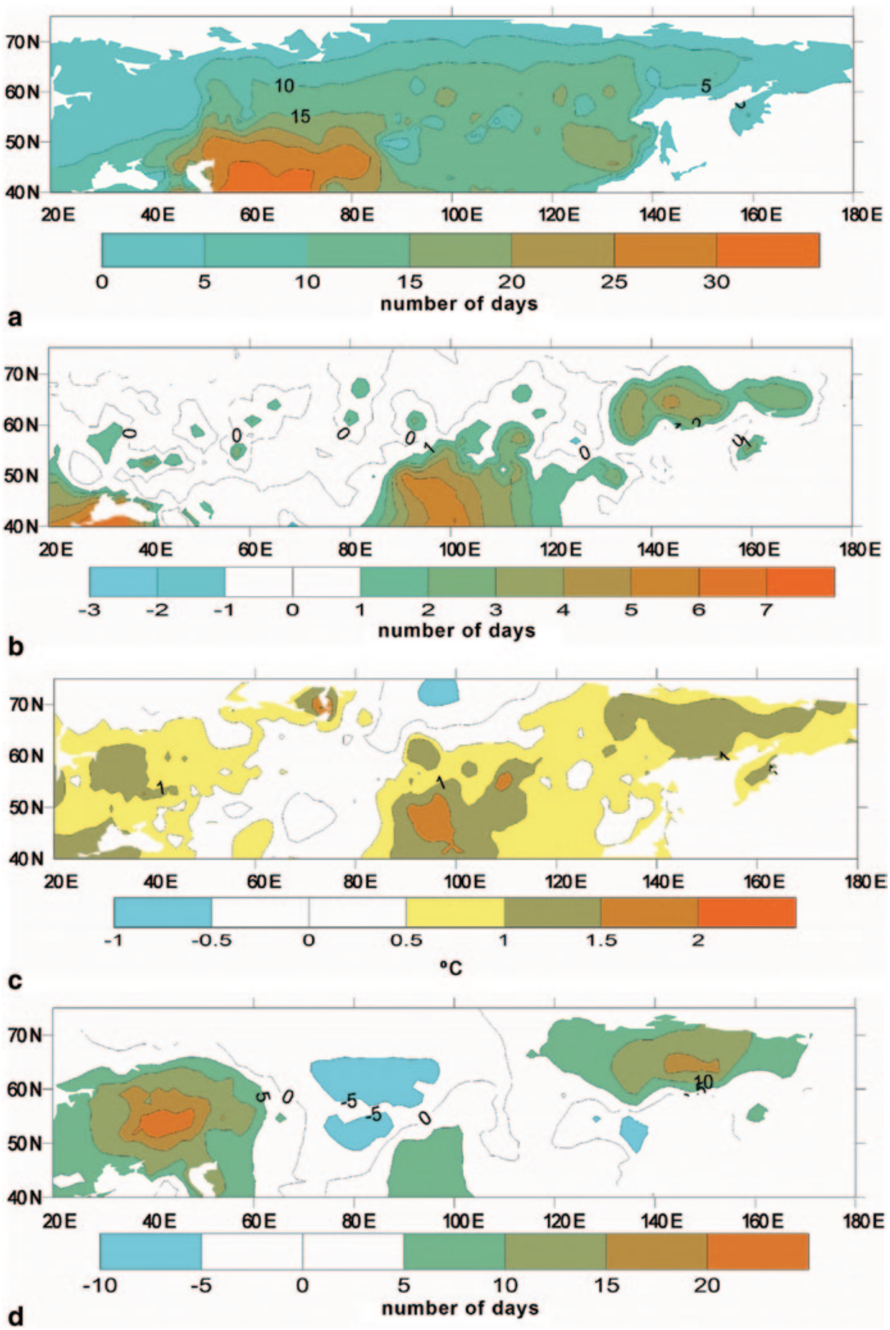


Fig. 6.1 Drought in July 2010 compared with drought climatic mean conditions in North Eurasia. Number of days with atmospheric drought in July during 1951–1980 (**a**); change in number of atmospheric drought days (**b**) and mean July air temperature in °C (**c**) during 1989–2010 as compared with 1951–1980; change in number of days with atmospheric drought in July (**d**) during 2010, as compared with 1951–1980

warming is almost of the same intensity as that in winter (Bedritsky 2008), although recently summer has been regarded as a nearly non-warming season on the subcontinent. The most significant patterns of temperature increase are in Central Asia, on the East European Plain, the Yamal Peninsula in the sub-Arctic, and northeast Siberia. The first and the last of these patterns result in increased atmospheric drought frequency in their respective regions, whereas the East European Plain pattern corresponds to several small patches of drought frequency increase. On the Yamal Peninsula, droughts are absent because of the low air temperature. Generally, the area of drought frequency increase is much less than that of air temperature increase, which is obviously compensated by precipitation increase in some regions.

6.4 2010 Anomalies Compared with Mean Climatic Values

The drought event of 2010, commonly referred to as the Great Russian Drought, greatly exceeded climatic norms of the East European Plain. The number of days with atmospheric drought in North Eurasia during July 2010 is shown in Fig. 6.1d. In the center of the drought-affected region, the drought frequency anomaly exceeded 20 days during that month. At the same time, a secondary maximum of drought frequency increase was observed in northeastern Siberia, at more than 15 days. An obvious wave-like structure of the anomalies (Fig. 6.1d) is of interest, with a maximum in Eastern Europe, minimum in Western Siberia, and another maximum in Eastern Siberia. The size of these patterns corresponds to the typical scale of large-scale circulations over the subcontinent. This aspect of climate anomalies is discussed below.

Figure 6.2a shows air temperature anomalies in July 2010 on the East European Plain, as compared with the norm of 1951–1980. The positive anomaly pattern is impressive for its size and scale; it covers a huge area from the Baltic Sea to Ural Mountains and the White Sea to Sea of Azov and Caspian Sea. The anomaly value exceeds 8 °C at maximum. The area of positive temperature anomaly roughly corresponds to where a blocking anticyclone was stalled for roughly 1.5 months, from the end of June through mid August 2010.

Precipitation anomalies in July 2010, as differences from the climatic norm of 1951–1980, are shown in Fig. 6.2b. Roughly the same region where the air temperature showed a large positive anomaly is occupied by a very strong negative precipitation anomaly. The lowest anomaly occupied a vast area, (shown in orange in Fig. 6.2b), from near to the Baltic region to the pre-Ural lowlands. Here, the anomaly is less than −60 mm, which means nearly zero or no precipitation in the center of the pattern. Local patterns of the precipitation anomaly had positive values only in the north near the White Sea, in the far south near the Azov Sea, and in the North Caucasus. The scale of anomalies of air temperature and precipitation in July 2010 on the East European Plain is unprecedented in the meteorological history of the region, which begins in the mid eighteenth century.

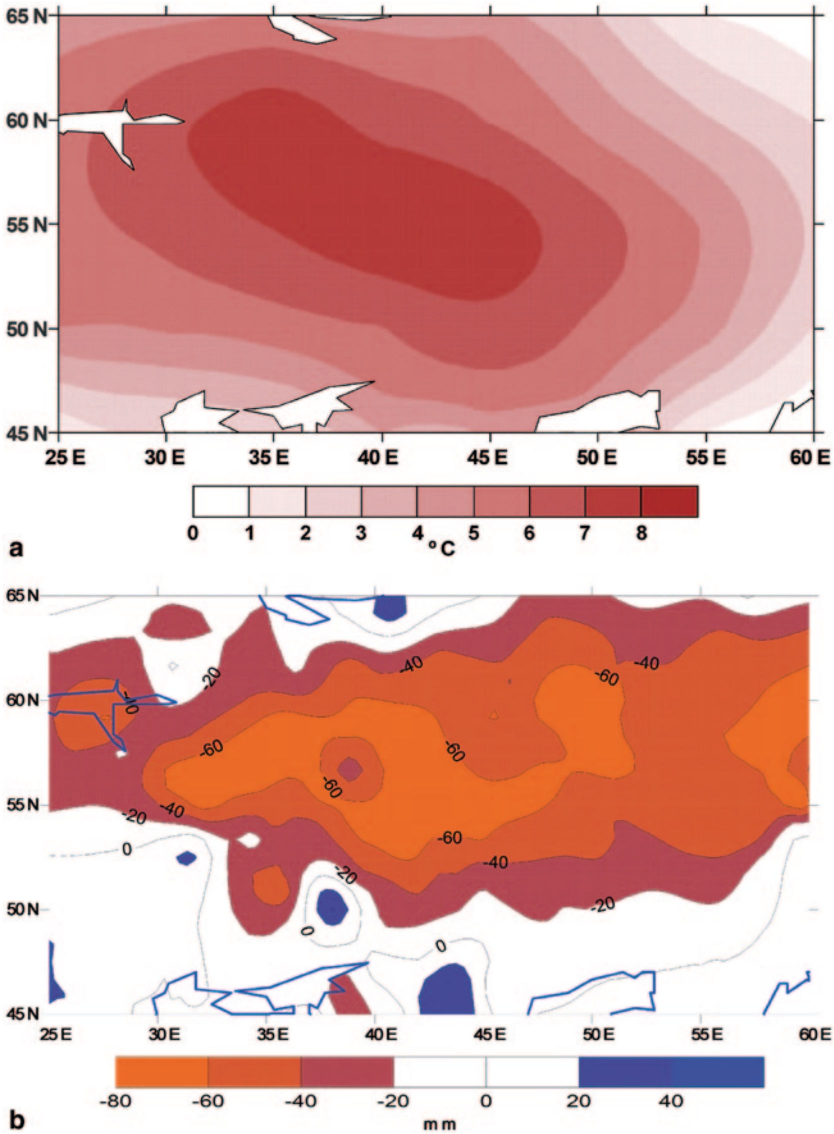


Fig. 6.2 Change of mean July (**a**) air temperature in °C and (**b**) precipitation accumulation in mm within European part of Russia (EPR) during 2010, as compared with 1951–1980

6.5 Classical Drought Indices and Anomalies During the 2010 Event

A number of specific drought indices have been developed to describe the calamitous 2010 drought in qualitative terms. Some of the well-known indices include the Ped drought index (PDI; Ped 1975), normalized anomaly of the Selyaninov hydrothermal coefficient (SHTC; Selyaninov 1928), and Palmer drought severity index (PDSI; Palmer 1965). These indices can be calculated as follows.

$$\mathrm{PDI} = \delta \mathrm{T} / \sigma_{\mathrm{T}} - \delta \mathrm{P} / \sigma_{\mathrm{P}}, \tag{6.1}$$

where δT and δP are monthly anomalies of temperature and precipitation, respectively; σ_T and σ_P are their mean square deviations, evaluated from monthly values of the entire time series.

$$\mathrm{SHTC} = \mathrm{P} / 0.1 * \mathrm{T}_{>10\,^{\circ}\mathrm{C}}, \tag{6.2}$$

where $T_{>10^{\circ}C}$ is the sum of daily mean air temperatures during a period when they exceed 10 °C; P is accumulated precipitation for the same period. In this paper, SHTS was normalized by its mean square deviation obtained from the entire time series.

For comparison of the indices, our study was limited to the territory of Russia west of the Ural Mountains (i.e., the European part of Russia or EPR), using data from 44 stations. The time span was limited to 1936–2010, and norms were calculated for this period. Monthly PDSI values were taken from NOAA archives (http://www.cpc.ncep.noaa.gov/products/). PDSI is calculated by a number of empirical relationships reflecting regional change of soil water content, standardized by its local climatic norm. Soil water content is determined by a simplified water balance equation, based on monthly values of precipitation and air temperature.

Table 6.1 shows drought intensities according to index values.

Each drought index was analyzed using three drought characteristics, maximum area, duration, and frequency of various areas and durations. Drought area was evaluated as a fraction of the entire EPR, and was calculated using GIS MapInfo.

The drought area was positively related to drought intensity, with correlation coefficients of 0.98 for SHTC, 0.96 for PDSI, and 0.94 for PDI. Correlation between time series of the drought indices was not ideal; the highest correlation was between SHTC and PDSI (0.81 for weak, 0.83 for moderate, and 0.76 for strong droughts). The SHTC-PDI relationships were strong (correlation coefficients 0.69 for weak, 0.76 for moderate, and 0.77 for strong droughts). The poorest correlation was between PDI and PDSI time series, 0.57 for weak, 0.70 for moderate, and 0.62 for strong droughts. The best agreement between drought areas according to the various indices was for years with the most extensive droughts.

Table 6.1 Drought intensity based on three drought indices

Drought intensity	Ped drought index (PDI)	Normalized Selyaninov hydrothermal coefficient (SHTC)	Palmer drought severity index (PDSI)
Weak	$1 \leq \mathrm{PDI} < 2$	$-1.25 < \mathrm{SHTC}_{\mathrm{norm}} \leq -1$	$-2 < \mathrm{PDSI} \leq -1$
Moderate	$2 \leq \mathrm{PDI} < 3$	$-1.5 < \mathrm{SHTC}_{\mathrm{norm}} \leq -1.25$	$-3 < \mathrm{PDSI} \leq -2$
Strong	$3 \leq \mathrm{PDI} < 4$	$-1.75 < \mathrm{SHTC}_{\mathrm{norm}} \leq -1.5$	$-4 < \mathrm{PDSI} \leq -3$
Extreme	$\mathrm{PDI} \geq 4$	$\mathrm{SHTC}_{\mathrm{norm}} \leq -1.75$	$\mathrm{PDSI} \leq -4$

Table 6.2 Frequency of wide-area extreme droughts of varying area in EPR during 1936–2010 (number of cases per year)

Drought area	PDI	SHTC normalized anomaly	PDSI
≥10%	0.01	0.07	0.11
≥20%	0.01	0	0.03
≥30%	0.01	0	0
Maximum area	37% in 2010	12% in 2010; 11.9% in 1936; 11.5% in 1938; 11.2% in 1972	24% in 1937 and 1939; 17% in 1938 and 1972; 13–14% in 1936, 1950 and 2010; 11% in 1975

The frequency of extreme drought (with area ≥10% of the EPR) according to the indices varied widely (Table 6.2). According to the PDI, the only drought with area ≥30% was in 2010. According to the SHTC and PDSI, there were no such drought areas. The frequency of droughts ≥10% of EPR area was 0.11 by PDSI estimation and 0.07 by SHTC. The greatest discrepancies were between PDI and PDSI, and the lowest between SHTC and PDSI.

Thus, the range of widespread extreme drought frequency was almost an order of magnitude, with the greatest discrepancies between PDI and PDSI and lowest between PDSI and normalized SHTC.

The year and area of most extreme drought determined depend on the index used (Table 6.2, Fig. 6.3). According to PDI analysis, the most widespread drought between 1936 and 2010 was in 2010, whereas SHTC analysis shows that droughts in 1936, 1938, 1972, and 2010 were approximately equal. According to PDSI, widespread droughts took place in the beginning of the study period, as well as in 1950, 1972, 1975, and 2010. Estimates of the 2010 drought area differ by a factor of three from one index to another. Overall, an outstanding ranking of the 2010 drought can be determined only from PDI, whereas SHTC and PDSI place it among other drought events of the twentieth century.

Local extreme droughts over less than 1% of EPR territory are not rare events in Eastern Europe. Consideration of these local droughts increases their frequency considerably (Table 6.3). For the entire 1936–2010 period, the highest drought frequency was obtained by PDSI (0.48) and the smallest by PDI (0.11). The SHTC frequency is nearer to PDSI, but less than PDI.

Thus, the range of drought characteristics between various indices decreases when taking into account local droughts. It is evident that PDI gives much lower drought frequency in the EPR than SHTC or PDSI. According to SHTC and PDSI, local droughts are possible in the EPR nearly every other year. Another important result of Table 6.3 is that drought frequency from all indices decreased during 1961–1990 relative to the previous 25 years, and then increased again after 1991, i.e., the period of global warming.

Yet another drought characteristic is the frequency of long-term drought (3 months or more). Table 6.4 illustrates temporal variations of long-term drought according to the indices.

The highest frequency was from PDSI and the lowest from PDI. According to SHTC and PDSI, the maximum of long-term droughts occurred during 1936–1960,

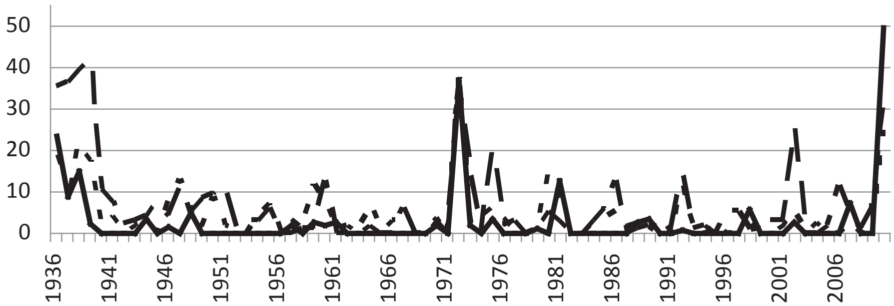


Fig. 6.3 Maximum area of extreme drought (%) from May through August during 1936–2010 in EPR, according to PDSI (*dashed line*), normalized SHTC (*dotted line*), and PDI (*solid line*)

Table 6.3 Frequency of extreme droughts in EPR from May through August during 1936–2010 (cases per year)

Years	PDI	Normalized anomaly of SHTC	PDSI
1936–1960	0.2	0.6	0.6
1961–1990	0.03	0.30	0.27
1991–2010	0.1	0.2	0.65
1936–2010	0.11	0.37	0.48

Table 6.4 Frequency of extreme droughts (longer than 3 months) in EPR from May through August during 1936–2010 (cases per year)

Years	PDI	Normalized anomaly of SHTC	PDSI
1936–1960	0.00	0.16	0.56
1961–1990	0.00	0.07	0.23
1991–2010	0.05	0.00	0.40
1936–2010	0.01	0.08	0.39

whereas PDI shifts this to 1991–2010. PDI and PDSI demonstrate an increase in the frequency of long-term droughts during 1991–2010 as compared with 1961–1990. SHTC does not show this peculiarity.

We generally conclude that during recent decades, i.e., under global warming, the frequency, intensity, and area of droughts in Eastern Europe have not increased significantly in a statistical sense.

6.6 Satellite-Derived Drought Index and its Peculiarities in 2010

An index of climatic extremes in dry areas has been developed by Zolotokrylin et al. (2012), involving satellite-based remote sensing data in drought analysis. It is called the Satellite Climatic Extremes Index (SCEI) and allows analysis of both positive and negative precipitation extremes in dry areas, and can be calculated by

$$\mathrm{SCEI_i} = -(\Delta \mathrm{A_i} / \sigma \mathrm{A} + \Delta \mathrm{Ts_i} / \sigma \mathrm{Ts}) + \Delta \mathrm{NDVI_i} / \sigma \mathrm{NDVI} + \Delta \mathrm{SWI_i} / \sigma \mathrm{SWI}, \quad (6.3)$$

where ΔA_i is the albedo anomaly in year i; σA is mean square deviation of albedo (during 2000–2011 for this study); ΔTs_i is the surface temperature anomaly in year i; σTs is the mean square deviation of surface temperature; $\Delta NDVI_i$ is the anomaly of NDVI (Normalized Difference Vegetation Index) in year i; σNDVI is the mean square deviation of NDVI; ΔSWI_i is the soil water content anomaly in year i; σSWI is the mean square deviation of soil water content.

The derived SCEI reflects major relationships between soil wetness and remotely sensed parameters (albedo, surface temperature, and others). For this study, a simplified version of the index was used, ignoring the last term on the right side of Eq. 6.3 (the one describing soil water content and its anomalies). Index values less than −1 can be regarded as signifying drought. Albedo, surface temperature, and NDVI data were obtained from the NASA Land Processes Distributed Active Archive Center (LP DAAC) website (https://lpdaac.usgs.gov/products/). Spatial resolution of the data is 0.05° in longitude and latitude. Periods used to study the 2010 drought were as follows: May 9–25 (Step 1), May 26–June 9 (Step 2), June 10–25 (Step 3), June 26–July 11 (Step 4), July 12–27 (Step 5), July 28–August 12 (Step 6), and August 13–28 (Step 7). SCEI maps of Eastern Europe (east of 30°E and south of 60°N) are shown in Figs. 6.4a, b, c, e, f, and g.

During Step 1 (May 9–25 in Fig. 6.4a), the main drought pattern appears in the southwest, in Kazakhstan. The size of this pattern reached 700–800 km, with the extent of strong drought 300–400 km. Thus, one may conclude that a significant drought pattern had already formed by mid May. In the western part of the East European dry belt, it was still very humid after snowmelt and some rain. During Step 2 (May 26–June 9 in Fig. 6.4b), the drought pattern from Kazakhstan spread north and northwest. In the center of the East European Plain and western part of the dry belt, humid conditions prevailed.

In mid June (10–25 June, Step 3 in Fig. 6.4c), the situation changed significantly. After June 20, a blocking anticyclone stalled over the central part of the East European Plain and Volga Basin, where it persisted until mid August. During this period, easterly and southeasterly winds prevailed, bringing hot and dry air from the main drought area in Kazakhstan. Therefore, the drought began to spread from Kazakhstan to large areas of the East European Plain. It reached 56°N in the eastern part of the plain and spread to its southwestern part. The humid areas had decreased in size and remained only in some locations. In Step 4 (June 26–July 11 in Fig. 6.4d), the entire study area was affected by drought (except southwest Ukraine), albeit weak in many locations. In the Volga Basin, several areas of strong drought had combined into one, extending from Kazakhstan to the Kama River basin and the Ural Mountains to Ukraine. During Step 5 (July 12–27 in Fig. 6.4e), the drought pattern spread farther west and partially to the north, where it formed in several minor areas. In Step 6 (July 28–August 12 in Fig. 6.4f), the drought on the East European Plain had separated in two areas, one to the east of the Volga River and the other in the northwestern study region. Finally, during August 13–28 (Step 7, Fig. 6.4g), the drought had become moderate and its area decreased. In many areas, especially in the north, rains enhanced soil water content and the drought had ended.

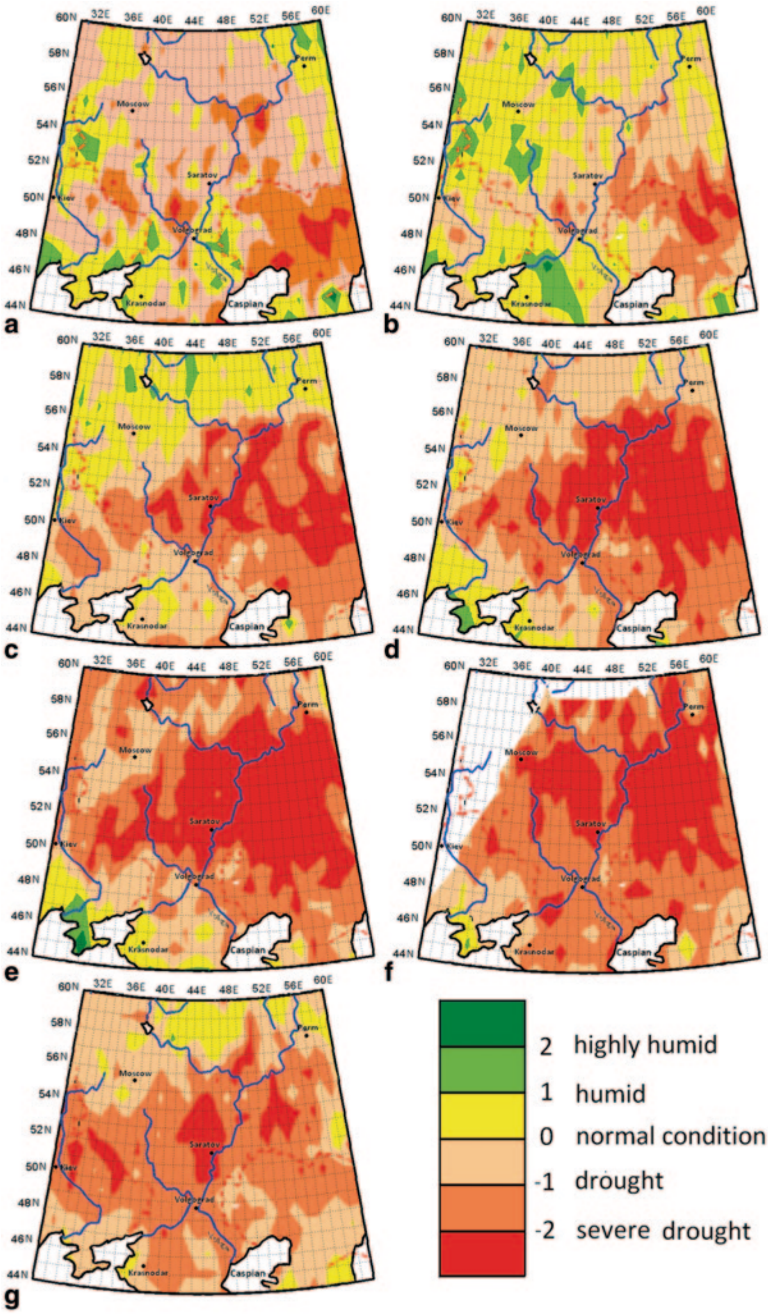


Fig. 6.4 Mean satellite-derived drought index during May 9–25 (**a**), May 26–June 9 (**b**), June 10–25 (**c**), June 26–July 11 (**d**), July 12–27 (**e**), July 28–August 12 (**f**), August 13–28 (**g**) in 2010, for the Eastern European, North Caucasus, and Caspian Sea regions

Thus, the SCEI permitted monitoring of spatiotemporal behavior of the 2010 extreme drought on the East European Plain, filling gaps in the observation network. The initial drought pattern, formed during May in Kazakhstan, spread to the northwest later in the season, probably because of feedback involving atmospheric dynamics.

6.7 Large-Scale Atmospheric Circulation Mechanisms of Eastern European Droughts

According to a previous study (Popova 2009), the main territory of North Eurasia can be divided into five regions, which are considered homogeneous by the type of summer (mainly July) air temperature variations during the second half of the twentieth century (Fig. 6.5). The EPR represents a region where the correlation between air temperature variations at its center with any point within its borders is no less than 0.55.

After interpolation of observed air temperature onto a regular grid and averaging over the EPR, we obtained a curve of mean July air temperature variation (Fig. 6.6). The plot shows mostly interannual fluctuations before the 1980s. After the mid 1980s, fluctuations of periods about 6–10 years and a trend of about 0.8 °C per decade can be distinguished.

The main atmospheric circulation mechanisms, the so-called Northern Hemisphere teleconnection patterns that determine the regional thermal regime, and their relative impacts on air temperature variability during 1950–2006, were revealed through multiple stepwise regression. These patterns include the EAWR, SCAND, and WP. The significant differences in temperature variations before and after the mid 1980s forced us to carry out separate analyses of circulation influence on temperature variation for each period. Table 6.5 demonstrates that the results for 1950–1984 and 1985–2010 are very different. Before 1984, July air temperature variability in the EPR is explained by an EAWR of 36 % (Table 6.5a), with a fraction (10 %) related to the May EAWR value. A small fraction of the temperature variations are

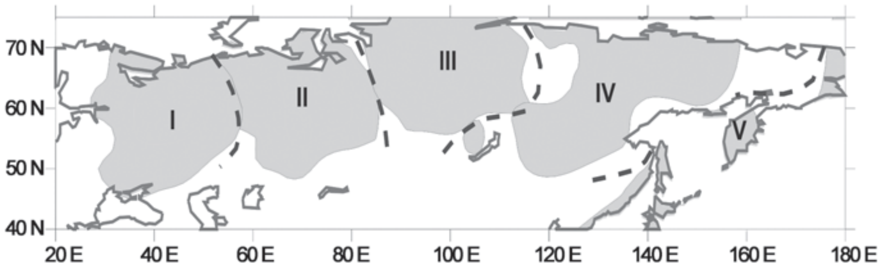


Fig. 6.5 Borders of regions (*dashed lines*) considered homogeneous by fluctuations of mean summer air temperature in North Eurasia. I, II, III, IV and V are region numbers

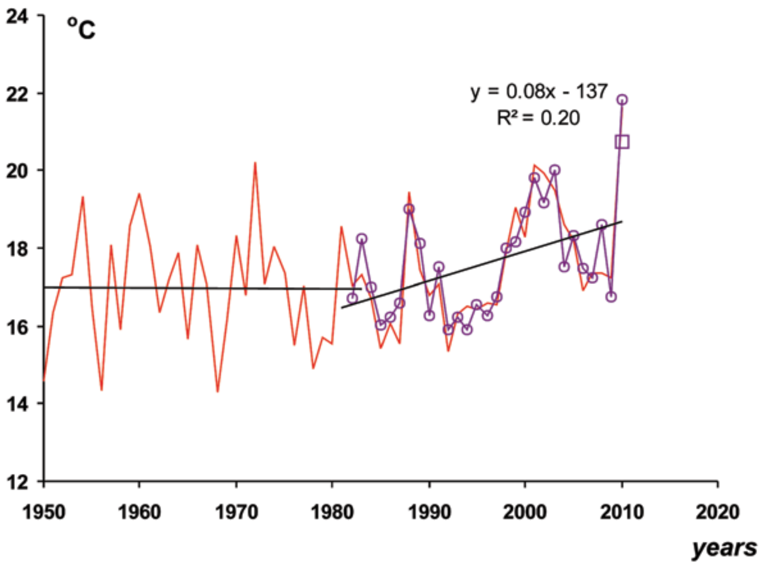


Fig. 6.6 Variations of mean July air temperature averaged over Region I (shown in Fig. 6.5). Linear trends are shown by *straight lines*; parameters of the trend during 1985–2010 are shown at top. *Red curve* with *circle markers* shows temperature calculated by regression shown in Table 6.5b. *Square marker* shows mean July 2010 air temperature, evaluated based on regression in Table 6.5c for 1985–2009

Table 6.5 Parameters of multiple stepwise regression between mean July air temperature averaged over EPR and atmospheric circulation indices

Index	Coefficient	Error	*R*	R^2%	*t* (*N*=33)	*p*
a. 1950–1984						
EAWR-7	−0.60	0.19	0.51	26	−3.19	0.00
EAWR-5	−0.44	0.20	0.60	36	−2.22	0.03
b. 1985–2010						
Index	Coefficient	Error	*R*	R^2%	*t* (*N*=21)	*p*
WP-7	−0.40	0.16	0.62	39	−2.58	0.02
EAWR-7	−0.52	0.13	0.77	59	−3.90	0.00
WP-5	−0.62	0.13	0.84	70	−4.85	0.00
WP-4	0.61	0.14	0.89	80	4.27	0.00
SCAND-7	0.46	0.15	0.93	86	2.96	0.01
c. 1985–2009						
Index	Coefficient	Error	*R*	R^2%	*t* (*N*=22)	*p*
WP-4	0.77	0.20	0.42	17	0.20	0.00
WP-5	−0.78	0.22	0.68	47	0.22	0.00

R correlation coefficient, R^2 (%) total fraction of explained variability, *N* degrees of freedom, *t* Student's criterion, *p* significance level explained by atmospheric circulation before 1984, which can probably be explained by the significant role of local processes within air masses, typical of summer at temperate latitudes. The period 1985–2010 was very different from 1950–1984; more than 80 % of air temperature variations in the ETR could be explained by the impact of circulation mechanisms (Table 6.5b). These are the same indices indicated for summer as a whole (Popova 2009), i.e., the WP, EAWR, and SCAND, with the leading role (59 %) belonging to WP. A curve that was determined based on the regression shown in Table 6.5b is plotted in Fig. 6.6. This curve is similar to observed temperature variations and completely reproduces the linear trend (0.82 °C per decade, with 24 % of its impact in the total dispersion).

It is important that 21 % of air temperature variability in July is explained by WP variations in the preceding spring, i.e., −10 % in April and 11 % in May. The impact of the spring macroscale atmospheric circulation on summer thermal conditions is probably related to the wave structure of the general atmospheric circulation outside the tropics, and can be important for predictability of air temperature anomalies and droughts. The regression of July air temperature for WP in April and May, given in Table 6.5c, demonstrates that almost half the July temperature variations can be explained by these index values. In Fig. 6.6, the square marker shows mean July 2010 air temperature, calculated by the regression for 1985–2009.

The pressure field and corresponding atmospheric circulation during July 2010 in Eastern Europe are as follows. The monthly mean geopotential field at 500 hPa (Fig. 6.7) reveals a strong ridge of maximum values extending from the subtropics to the northwest via the Caucasus-Caspian region and the northern EPR. The 500 hPa anomaly (i.e., its difference from the mean 1950–2010 regime) has a significant pattern with closed isolines, centered slightly northwest of the absolute maximum of the ridge. This pattern reflects the main direction of atmospheric flow,

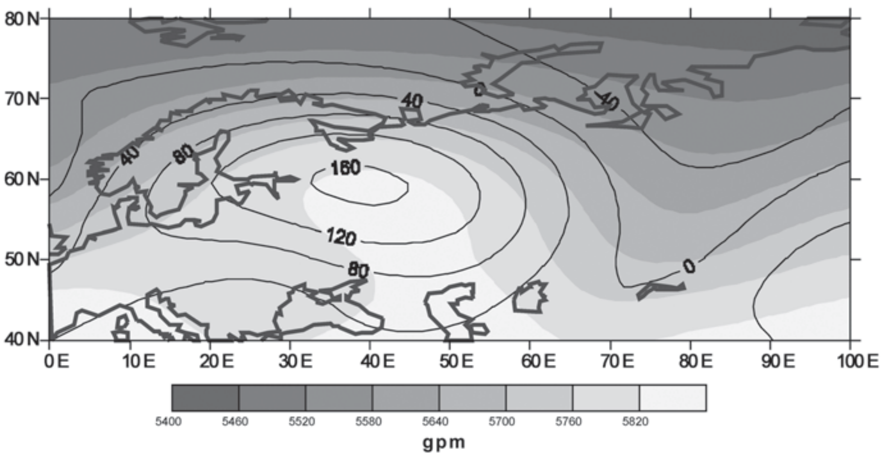


Fig. 6.7 Absolute height (gpm) of geopotential field (*grey* gradations) at 500 hPa and its anomaly (*isolines*, as compared with mean for 1950–2010) during July 2010

which transported hot air masses to the East European Plain from the deserts of the Near East and blocked cold air masses from entering the region.

Comparison of the 500 hPa anomalies in July 2010 with the field of correlation between the geopotential height and WP index for July (Fig. 6.8) demonstrates their strong similarity. The anomaly is in almost the same region where the negative correlation is centered, with the highest correlation reaching −0.6.

We calculated the difference between anomalies of the geopotential field at 500 hPa for years with negative and positive WP index anomalies in July. Such an anomaly field is plotted in Fig. 6.9 for 1985–2009 and 1985–2010. These fields are similar to the one shown in Fig. 6.8, although its center (Fig. 6.9) is shifted slightly westward and oriented more toward the northeast. The absolute value of the anomaly was lower than in 2010, especially for the 1985–2009 mean. When including 2010 in the analysis, the anomaly widens, especially east-southeast from the center, preserving the general structure of the field.

It is possible that the widening and increase of the 500 hPa geopotential anomaly in July 2010 could be influenced by its collocation with WP index anomalies in July and May. Figure 6.10 shows that the anomaly field of geopotential height at 500 hPa in July, calculated as a difference for years with negative and positive WP index in May, has a maximum extending in the west-east direction, and occupies the central EPR. Correlation between the WP in May and 500 hPa geopotential in July (Fig. 6.11) also indicates their significant correlation in the central and southern EPR.

Stepwise multiple regression analysis showed that the teleconnection indices responsible for mean July air temperature variations in the EPR are the WP in April, May and July, EAWR in May and July, and SCAND in July. Curves of interannual variations of the indices are presented in Fig. 6.12.

The curves in Fig. 6.12 show that all time series had strong interannual variability. Fluctuations with periods from a few to 20 years are typical for all time series, but they are expressed in various ways. The most pronounced quasi-periodic fluctuations are seen in the July WP indices for period 20 years and July EAWR for 10

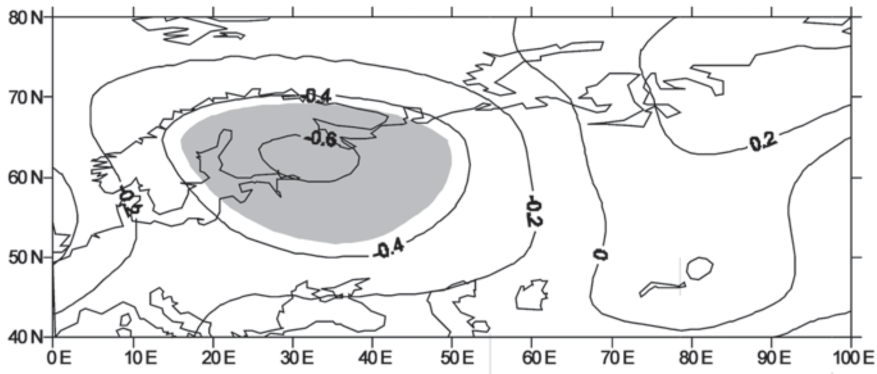


Fig. 6.8 Linear correlation between WP index and geopotential height at 500 hPa in July for 1985–2010. Statistically significant correlation is highlighted in *gray*

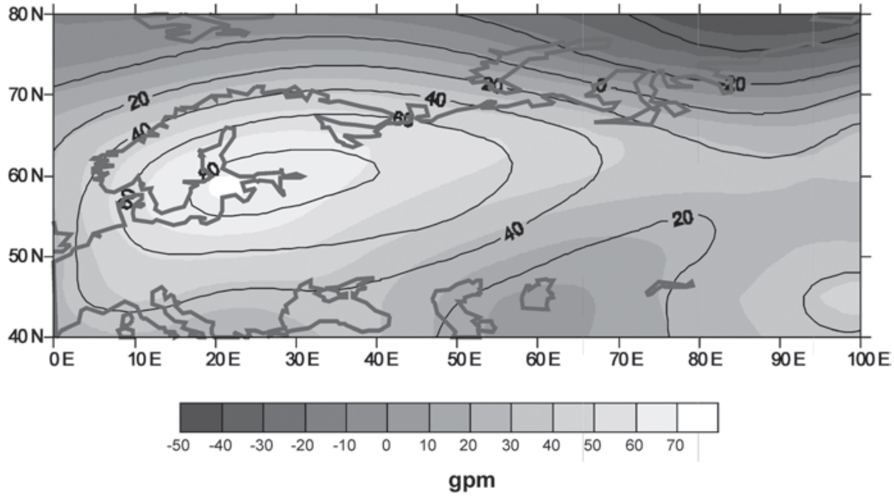


Fig. 6.9 Difference between mean geopotential heights (gpm) at 500 hPa in years with negative and positive anomalies of WP index in July (*gray shading* is for 1985–2009 and *isolines* for 1985–2010)

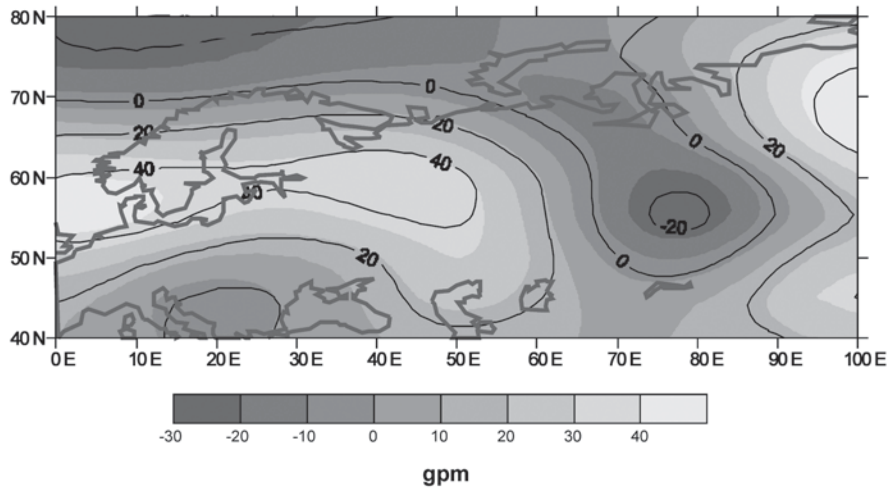


Fig. 6.10 Difference between mean geopotential heights (gpm) at 500 hPa in July for years with negative and positive anomalies of WP index in May (*gray shading* is for 1985–2009 and *isolines* for 1985–2010)

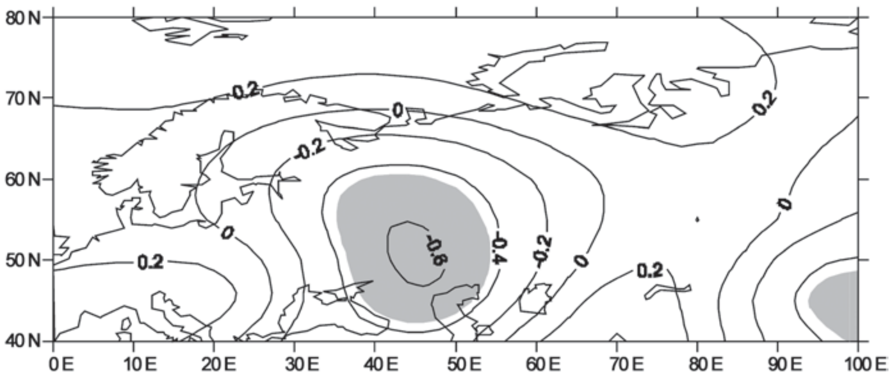


Fig. 6.11 Linear correlation between WP index in May and geopotential height at 500 hPa in July for 1985–2010. Statistically significant correlation is shown by *gray shading*

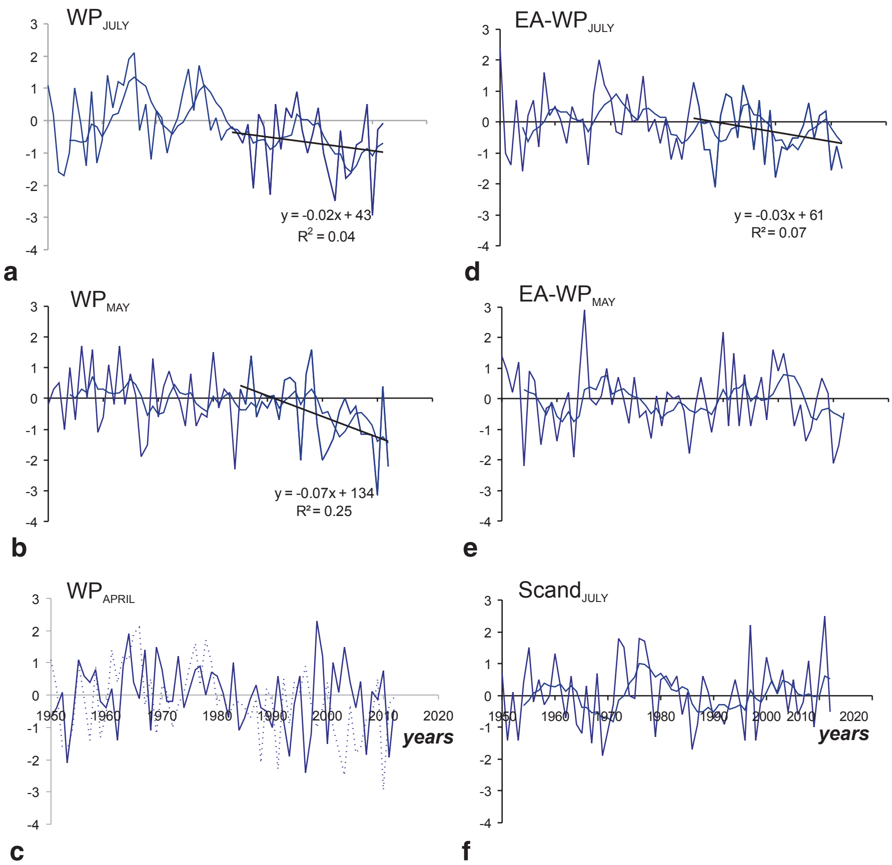


Fig. 6.12 Variations of teleconnection indices: WP for July (**a**), May (**b**) and April (**c**); EAWR for July (**d**) and May (**e**); SCAND for July (**f**). *Thick lines* indicate 5-year running mean; *straight lines* represent linear trends. Trend equations for panels a, b, and d are given. *Dotted line* in panel c represents mean July WP index for comparison

years. In other time series, fluctuations were less pronounced in amplitude (SCAND in July) or unstable (EAWR in May). The low-frequency component is probably the most distinctive feature, and is typical for WP in May and July. In the former case (May in WP), this component is apparent in the decreasing trend beginning in the mid 1980s, comprising a significant fraction (25 %) of total variability. Average values for 1950–1984 and 1985–2012 were statistically different. In the latter case (July in WP), one can also see a negative trend. While their fractions of total variability were not large, mean values before and after the mid 1980s were very different, a contrast that was statistically significant. There were some differences between the two periods for WP in April and EAWR in July, with the latter having a slight trend since the mid 1980s. However, only WP in July and May had a strong shift to negative values beginning in the mid 1980s. Another peculiarity of the WP indices in July and April is their negative relationship, with correlation coefficient −0.46 at significance level 0.02 for 1985–2012 (Fig. 6.12a).

Qualitative changes in the WP time series for July, May, and April reveal qualitative differences between circulation in the Northern Hemisphere extratropics during spring and summer before and after the mid 1980s. Clearly, these changes are related to North Pacific pressure systems and can be treated as weakening of zonal atmospheric circulations, which is expressed by negative anomalies of the index in July and May during 1985–2012. Effects of the aforementioned pressure systems are probably so great (at least in summer) that the weakening is clear in the entire extratropical zone of the Northern Hemisphere, resulting in more frequent blocking events in the Atlantic-European sector.

Anomalies of the North Pacific pressure systems are probably associated with changes in heat and water fluxes between ocean and land. It is known that in the North Pacific region, these are influenced by the Southern Oscillation. We performed linear correlation between the El Niño Southern Oscillation (ENSO) index averaged over January–April and the WP in April, May and July. This showed that the relationship appeared for WP in May only and it was absent during 1950–1984, although since the mid 1980s it was pronounced (for 1985–2012, with correlation coefficient reaching 0.54). There was no relationship between the ENSO index and mean EPR air temperature in July, either before or after the mid 1980s.

6.8 Conclusion

We analyzed various empirical data reflecting the frequency and intensity of atmospheric droughts in North Eurasia—Russia and neighboring countries. We focused on the East European Plain, which suffered greatly during the 2010 heat wave known as the Great Russian Drought. Logically, the maximum drought frequency was in Central Asia, where the entire month of July normally has continuous drought conditions. The northwest, north, and northeast of the subcontinent, as well as the Black Sea and Pacific coasts, normally have only occasional droughts in July. During recent decades, i.e., under global warming, there has been a significant increase in the frequency of atmospheric droughts in only a few limited areas and northeast Siberia, where drought frequency remains low. The 2010 event was exceptional in terms of air temperature, precipitation, and drought conditions over most of the East European Plain.

Various indices of drought conditions, such as the Palmer index, Ped index and Selyaninov hydrothermal coefficient, were calculated for 1936–2010 across the East European Plain. All indices show an increase of drought frequency during 1991–2010 as compared with 1961–1990, although different indices place the maximum drought frequency in different periods. From some indices, the 2010 drought was extreme over the analyzed period, but other indices place it alongside other twentieth-century drought events. A specific index of drought conditions was proposed, based on satellite-measured albedo, surface temperature, and NDVI. We investigated detailed spatiotemporal structure of the 2010 drought dynamics across the East European Plain, North Caucasus, and Caspian Sea regions, facilitating observation of the spread of drought conditions from Central Asia to the East European Plain.

Air temperature anomalies over the East European Plain were analyzed together with characteristics of large-scale atmospheric circulation for 1950–2010. Air temperature in July during 1950–1984 varied without any trend and with primarily high-frequency fluctuations. After 1985, the fluctuations attained a period about 8–16 years and a significant trend of 0.8 °C per decade was revealed, with the latter providing 20 % of total variability. The periods before and after the mid 1980s were also very different in their circulation mechanisms, thereby explaining the temperature variations. Before 1984, only 40 % of the temperature variations could be related to the atmospheric circulation indices, mostly in the EAWR. However, since 1985, about 86 % of those variations were described by the circulation, 60 % of which were related to the WP index in July, May, and April. Almost half the July air temperature variations could be explained by the WP indices for May and April. This allows prediction of future air temperature anomalies in some cases, albeit not for every year. The relationship between July air temperature over the East European Plain and the WP indices for different months was negative; the smaller the index was, the higher the temperature. This tendency reveals weakening of zonal atmospheric flows over North Eurasia since the mid 1980s. This corresponds to increased frequency of blocking anticyclones, thereby generating higher drought frequencies in the region.

Acknowledgement The study was supported by the Russian Foundation for Basic Research, grant No. 13-05-41058.

References

Barnston AG, Livezey RE (1987) Classification, seasonality, and persistence of low frequency atmospheric circulation patterns. Mon Wea Rev 115:1083–1126

Barriopedro D, Fischer EM, Luterbacher J, Trigo RM, Garcia-Herrera R (2011) The hot summer of 2010: redrawing the temperature record map of Europe. Science 332:220–224

Bedritsky AI (2008) Assessment report on climate change and its impact in the territory of Russian Federation, vols 1 and 2. Roshydromet, Moscow (in Russian)

Blunden J, Arndt DS, Baringer MO (2011) State of the climate in 2010. Bull Am Meteorol Soc 92(6):S1–S236

Grumm RH (2011) The Central European and Russian heat event of july–august 2010. Bull Am Meteorol Soc 92(10):1285–1296

Jiang T, Qiang Z, Deming Z, Yijin W (2006) Yangtze floods and droughts (China) and teleconnections with ENSO activities (1470–2003). Quat Int 144:29–37

Lau WK, Kim K (2012) The 2010 Pakistan flood and Russian heat wave: teleconnection of hydrometeorological extremes. J Hydrometeorol 13:392–403

Palmer WC (1965) Meteorological drought. US Department of Commerce Research Paper vol 45, pp 1–65

Ped DA (1975) On the index of drought and excessive humidification. Proc Hydrometeorol Cent USSR 156:19–38 (in Russian)

Popova VV (2009) Contemporary changes of surface air temperature in the North Eurasia: regional tendencies and the role of atmospheric circulation. Izv Akad Nauk Geogr 6:59–69 (in Russian)

Selyaninov GT (1928) On agricultural estimation of the climate. Proc Agric Meteorol 20:165–177 (in Russian)

Vasiliev AA, Belinskiy ON (2001) Main kinds of hydrometeorological dangers and their distribution over Russia territory. Natural dangers of Russia 5. Hydrometeorological dangers. Kruk, Moscow, pp 14–24 (in Russian)

Zolotokrylin AN, Titkova TB, Cherenkova EA, Vinogradova VV (2012) Satellite index for evaluation of climatic extremes in dry areas. Mod Stud Earth Remote Sens Sp 9:114–121 (in Russian)

Chapter 7
Geographical Information System for the Amur River Basin

Viktor V. Ermoshin

Abstract In this study, questions about the formation of some uses for the Amur River Basin geo-information space are considered. Increased interest in this basin has arisen in connection with current trends in geopolitical and geographical integration. The Amur Basin is a regional transboundary geosystem. Formation of electronic layers included in the base geographical block, base thematic block, and some layers of the auxiliary thematic blocks are discussed. Further steps in realization of the project and use of its results in future activities are planned. A complete geo-information space generated from unified principles is necessary for sustainable development planning.

Keywords GIS • Amur River Basin • Transboundary geosystem • Geo-information space • Mapping

7.1 Amur Basin Geo-Information Space

Intensive research on the Amur River Basin was carried out in the late nineteenth and early twentieth centuries (e.g., Venyukov 1970; Przewalski 1947; Obruchev 1952; Maak 2007). Anuchin (1896, 1897) was among the first to attempt an integral assessment of the natural conditions, population, and economy of the region. A number of applied scientific works resulted from an Amur expedition early in the twentieth century (Korotky 1912; Mitinsky 1911) to investigate possibilities for economic improvement and to further population migration and development of industry. A substantial contribution to the understanding of the natural environment of the Amur River Basin was made by the Russian-Chinese Amur expedition in the late 1950s (Nikolskaya and Chichagov 1957). This research formed the basis for considering the Amur River Basin not only within individual countries but also as an integral geographic feature, the parts of which are closely interrelated. Recent attention to geopolitical and environmental problems in this region has increased

V. V. Ermoshin (✉)
Pacific Geographical Institute FEBRAS, 7 Radio St., 690041 Vladivostok, Russia
e-mail: yermoshin@tig.dvo.ru

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_7

interest in environmental issues, land resources, and joint economic interactions and development between the Russian Far East and northeastern China (Kachur et al. 2001; Baklanov and Ganzei 2004; Karakin and Sheingauz 2004).

More often than other physiographic or landscape units, a river basin is considered a stable and unambiguously identifiable surface object (Korytny 2001). River basins with regional dimensions have an integral and complex ecosystem. The Amur River Basin, covering the territories of three countries, is a model transboundary geosystem (Ganzey 2004; Baklanov and Ganzei 2008). A distinguishing feature of recent research is the fact that information analysis within the basin is performed as a rule on large administrative-territorial divisions. The use of such large-scale data is necessary because information for certain parts of the Amur River Basin is incomplete, heterogeneous, and irregular in its detail, method of collection, and handling. Planning and implementation of balanced economic and natural resource management policies should be done in concert with the contiguous border territories of adjacent states. The interrelationship of natural resources in such border zones necessitates their analysis in the framework of a common transboundary territory, in other words, a regional geosystem (Baklanov and Ganzei 2008). Further studies and planning for development of this region and its individual parts require not only more detailed but also more homogeneous and correlated information about its natural features, practical uses, and anthropogenic changes. A computer-based multidimensional model of a region's common structure can serve as an information basis for adequate reflection of the geographic space (Yermoshin 2006a). Solving problems related to visualization and analysis of space distributed information is impossible now without use of geo-information mapping and geographic information system (GIS) technologies—modern methods developed at the nexus of geography, nature management, and cartography.

Space distributed information translated into the two-dimensional cartographic language of maps, map sets, and atlases has been a basis for regional development planning since ancient times. The information specificity of maps is manifested through transformation of geo-information and map features, which are carriers of such geo-information. Kanakubo and his co-authors identified three basic uses of maps, visualization, interpretation, and navigation (Kanakubo 1993). Next, using the 3D Digital Earth Model as a basis, we can create 3D models of various properties of the geographic space. These properties include vegetation, soils and landscapes, plus structures of the economy. Accordingly, when we implement visualization, we can use different mapping techniques, perspective, flying, anamorphosis and others.

The necessity of developing complex geo-information support, analysis, and mapping for sustainable development has been discussed (Tikunov and Tsapuk 1999; Batuyev 2003; Cherkashin et al. 2002). The creation of a geo-information analytical base will address problems of permanent management of natural resources and sustainable development of the associated territories. The focus of planning, use, and environmental assessment shifts from objects to territories, where local government bodies hold significant power. Additional prerequisites for a geo-information analytical base are as follows: a high level of technological development in information support; public awareness of the necessity of administrative information support; and a sharp rise in requirements for that support.

Information should be organized and presented in such a way that it complies with the following basic principles:

- Detail and completeness: provision of land-use planning at different management levels
- Spatial distribution and identity: strict correlation of information with particular territorial units on different levels
- The possibility of mobile addition and correction is necessary for operative management and use when changing priorities and tasks (Yermoshin 2003).

The coordination of heterogeneous geo-information is important for addressing specific territorial problems and regional projects. Tikunov identified three stages of compatibility for geo-information acquired from different sources (Tikunov and Tsapuk 1999). The first stage is sorting within the particular system of information by time, territory, and specific content. The second stage is coordination, i.e., optimization of information from different sources. In the third stage is integration of information, with creation of maps or electronic layers.

With reference to geographic exploration, one must speak not only of geo-information support but also of common geo-information space. In addition to technical and technological aspects, the method, at the root of which the geographic approach lies, should also be addressed. Accordingly, geo-information and cartographic support for regional management and sustainable development is considered an independent line of research, designed to form a common geo-information space for a particular territory. Generalizing an assembly of properties, in our opinion the geo-information space (GeoInfoSp) exists as an independent phenomenon and is a subjective-objective reflection of a geographical space (Fig. 7.1). One can agree with Tikunov that the database structure and geo-information as a whole should reflect the structure of geographical systems in both territorial and informative aspects (Tikunov and Tsapuk 1999; Tikunov 1991).

A unified GeoInfoSp for the Amur River Basin transboundary geosystem has great scientific and practical importance as a basis for sustainable natural resource management and environmental safety of the countries within the basin. The urgency of this work arises from the increased adverse contribution of the Amur River to pollution in the Sea of Okhotsk, which has reduced phytoplankton productivity and fishery resources (Shiraiwa 2010).

The use of modern geo-information methods, such as remote sensing, GIS technologies, and vector and grid representations of space distributed information, provides new information on the natural resource potential and ecology of the Amur River Basin and forms a reliable information base for natural resource management and improvement (Baklanov et al. 2005). GeoInfoSp makes it possible to solve ecological problems within the basin as a whole. This system reveals landscape structure and regularities of land-use organization in different parts of the basin, allowing for unified land-use planning, priority setting, and restrictions on certain types of economic activities.

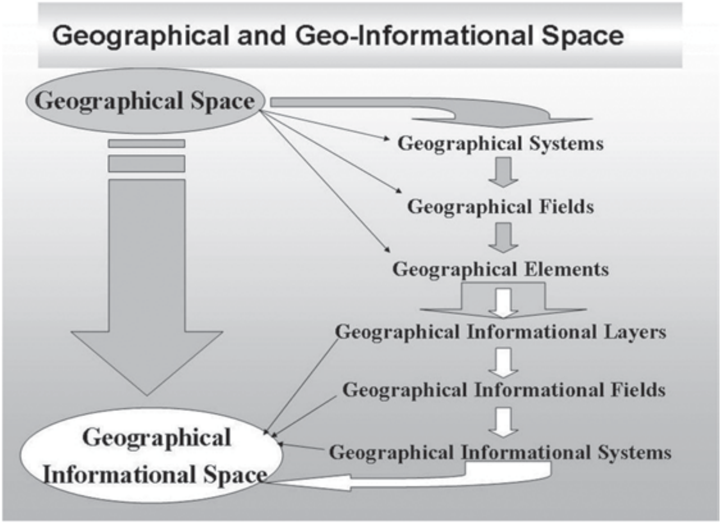


Fig. 7.1 Relationship between geographical and geo-information spaces

Earlier, we described fundamentals of forming the geo-information space of territories, i.e., hierarchical patterns, completeness, information kernels, and invariants, as well as the relationship between geo-informational and geographical spaces (Yermoshin 2003; Ermoshin et al. 2005). The geo-information space is a multi-level, poly-layer, territorial-concrete, structured information-based model of geographical space.

Hierarchic levels are formed on the same scale used for sustainable natural resource management. These levels are: regional (a group of administrative subjects, federal district, or physiographic country), with scale less than 1:1 million; subregional (administrative subject; physiographic area or province), scale 1:200,000–1:1 million; local (administrative or physiographic district), scale 1:50,000–1:100,000; and detailed (separate settlement, landscape), scale 1:25,000 and greater. Projects covering transboundary territories can be considered regional despite their international character. At each level, the following steps are successively addressed: formation of base information core; selection and/or ratio of territorial cells, which are structural information units of the level under consideration; reduction of different thematic materials to a common standard; determination of structural relations between thematic layers; and determination of information details for each particular level (Ermoshin 2002).

The basic topographic and thematic layers as well as individual thematic and managerial informational layers are formed at each level for the territory under consideration. Basic topographic layers include relief, river networks, lakes, road networks, population centers, and boundaries. Basic thematic layers include vegetation, landscape, forest, land users and land use, natural resources, conserved and protected territories, and geomorphology. Specific thematic layers are determined with due accounting for natural and economic features of the specific territory and the problems for which the geo-information space is created to address. For example, for a local administrative district, these layers can include recreational resources, fishery resources, non-woody forest resources, and functional zones.

All layers have common borders and/or direct relationships that conform consistently with each other with regard to information content, much as in integrated atlas mapping. Thus, the layers form a thorough, logical spatial series. Almost every series has at least one connection with another. Therefore, most layers directly or indirectly have common invariants. Some examples of consistent information coordination between electronic layer series include the following: river networks—relief—road networks—settlements—land users and land use; river networks—state (administrative) boundaries—conserved and protected territories—recreational resources; river networks—vegetation—landscapes—functional zones (Ermoshin 2002).

The high-priority problem upon which successful sustainable development and natural resource management planning depends is a realization of territorial divisions, including functional zoning. The geo-information approach can be used for this purpose in two ways. On the one hand, GeoInfoSp can be used to solve problems of district divisions and land-use planning for territories on different levels. On the other hand, GeoInfoSp is a necessary and adequate information base for planning and monitoring of natural resource management and sustainable development. The results of dividing districts into information layers with appropriate attributive bases are also a component of GeoInfoSp, and are used as elementary information cells for land-use planning and environmental assessment. In other words, the division into districts and zoning (including land-use planning), presentation of results in the form of information layers and databases, and accumulation of those layers and databases by a unified GeoInfoSp are necessary stages for planning sustainable development and natural resource management of a territory. From this follows the relatively simple but weighty conclusion that the development of information in GeoInfoSp is cartographic and geographic rather than problem-specific.

To clarify, we can draw parallels between a sequence of GeoInfoSp formation, its basic blocks, and some basic stages of mapping: inventory, evaluative, and predictive-recommendatory (Table 7.1).

Interrelationships result from the fact that the base thematic layers and, in part, the individual layers correspond to inventory mapping, whereas the other individual layers and managerial layers correspond to evaluative and predictive-recommendatory mapping, respectively.

Each particular project in natural resource management planning and problem solving at any level must pass through all the stages, from inventory to predictive-recommendatory. As projects are realized and information accumulated, the completeness or density of the space (i.e., number of layers) increases and saturation (number of layer characteristics) grows. Accordingly, the volume of work in the first stage, which forms the information core, decreases for all subsequent projects. This is especially clear at regional and sub-regional levels, where the entire territory is involved in the next project almost every time.

Table 7.1 GeoInfoSp forming and mapping for natural resource management

Mapping type	Type of territory division	Type of geoinformation	Stage of formation of GeoInSp
Inventory	Division into districts (typological and individual)—division of common geographical space according to its numerous properties on the basis of specified classifications including hierarchical ones	General	Production of the system of inventory cells Formation of information thematic cores of the polystratified GeoInfoSp
Evaluative	Division into districts according to new characteristics without division and integration of inventory cells		Determination of relations in the structure of inventory cells
	Zoning is integration of inventory cells according to some general properties or characteristics	Special	Increase in the density and saturation of the GeoInfoSp—forming of additional individual layers
Predictive-recommendatory	Functional zoning—integration of inventory and evaluative cells on the principle of possible management and use	Evaluative and management	Production of the administrative in formation block of the GeoInfoSp

There is specificity in the structural and informational aspects for each particular environmental or natural resource management project in the geo-information space. General structural and geo-informational concepts and rules as well as methodological procedures are identified. Access to spatial data resources, management, and analysis tools is essential. Open access to data implies a large number of simultaneous users and application integration of heterogeneous data at user workstations. As an example of the influence of the possibility of open access to spatial data and simple operation tools, one may remember public resonance with Google Maps. Data for the spatial data infrastructure for regional development should be selected purposefully, based on the specificity of territory and setup tasks (Baklanov et al. 2010).

An algorithmic combination for spatial superposition and ratios of separate geo-information layers gives the opportunity to form any type of composite cartographical product for specific purposes and to solve a number of spatial geosystem problems, including the following:

- Geographic partitioning (zoning, separation into districts) aimed at allocation of homogeneous areas and complete geosystems of various types
- Allocation of areas with a certain set of characteristics or separate components
- Allocation of territorially expressed anthropogenic factors affecting the environment
- Estimation of correlations between natural components, populations, and economies
- Estimation of stability of various types of geosystems

- Predictive estimates of geosystem dynamics, including those under the influence of anthropogenic factors
- Development of regional natural resource management and sustainable development programs
- Organization of environmental monitoring (Baklanov et al. 2005)

The foregoing conforms fully to the concept of spatial data infrastructure (SDI), which has gained ground in recent times (Koshkarev et al. 2008). SDI includes three large groups of datasets: geoportal, a portal to search, find, assess, display, and receive spatial data; spatial metadata base, a distributed spatial database; and resources for spatial datasets and spatial data, including basic topographic and thematic spatial data (digital thematic layers, GIS). GeoInfoSp is formed by geographic and thematic layers of the third group, whereas information used to create the layers is present in the first two groups of datasets.

7.2 GIS Structure of the Amur River Basin

Environmental problems are associated with natural phenomena and, more importantly, with economic, political, sociological, historical, and philosophical factors. Environmental problems in the Amur River Basin should be recognized as international as well as domestic issues within Russia, China, and Mongolia (Narita et al. 2004). Total area of the basin is nearly 2 million km^2, of which Russia occupies 50%, China 42%, and Mongolia 8%. Spatially distributed information about basic environmental components at several hierarchical levels, at approximate scales 1:2.5 million, 1:500,000, and 1:100,000, is required for proper solution of the main and complementary tasks of ours and future projects. The end result should be a hierarchical, spatially structured geo-information system with nested geo-coded information. In this chapter, we describe the formation of thematic layers at scales 1:1 million and 1:2.5 million (regional hierarchical level) as components of a unified geo-information space of the Amur River Basin.

Blocks and elements of the geo-information space for the Amur River Basin geosystem should be constructed, corrected, and coordinated in terms of classifications and space, for the territories of Russia, China, and Mongolia. The following electronic layers with appropriate attributive databases were chosen: base geographic (river networks, relief, boundaries, settlements, and road networks); base thematic (geology, geomorphology, vegetation, soil cover, climate, and landscape complexes); secondary thematic (land use, anthropogenic change, wetlands, and specially protected natural areas); and managerial (land-use planning of various types).

Populating the base thematic and base geographic blocks occurs in the inventory stage. The secondary thematic block is populated in the evaluative stage, and the managerial block in the predictive-recommendatory stage (Table 7.1). These blocks are the information support for planning sustainable natural resource management and forming the regional geo-information space of the integrated transboundary Amur River Basin geosystem.

Formation of a geo-information space in international transboundary territories is an aggregate solution of a number of subjective and objective problems, political, geo-informational, information exchange, technical, and technological (Ganzey 2004; Yermoshin 2006b). Examination and mapping of geographical objects within the territories of several countries involves great difficulties and is distinguished by particular specificity. The Amur River Basin is a good case study for improvement of research methods for regional geographic structures, such as transboundary river basin geosystems.

Data from the Chinese and Russian sides of the basin came from various sources and must be processed, corrected, and interrelated. Prior to beginning such work, it is necessary to stipulate all possible technical parameters of information collection (such as scale, projection, detail, classification, language, and others) to avoid problems. A specific feature of projects within transboundary territories is discrepancy between initial data from the various countries (Ermoshin 2004). Accordingly, there are problems related to geo-information exchange, interplay, and formation of a uniform geo-information space, including the following:

- Almost all common geographical and thematic layers have varying degrees of incompatibility along state boundaries
- Geographic names vary by country; therefore, a uniform principle of cartographic representation and adjustment of names is required
- There are distinctions in understanding of the same objects, e.g., nature reserves and types of land use
- Estimates of anthropogenic factors, ecological standards, and restrictions vary
- Classification of complex objects (roads, settlements, types of vegetation, types of land use) varies by region; because different substantial notions, principles, and fundamentals can be used in classification and gradation numbers do not coincide, definition of a common base is necessary

Development of geo-informational support for the geo-information space projects took place in four stages. The first included creation of a principal block diagram, construction of the information structure of the blocks, and determination of the sequence of coordination between information layers and blocks. The second stage included creation of vector base geographic information layers, construction of vector base information thematic layers, unification of classifications and legends, and coordination of spatial information along state boundaries. The third stage involved compilation of information layers and electronic maps of land-use and landscape complexes, and analysis of environmental and natural resource modifications. The fourth stage included functional zoning (land-use planning) with specification of priorities, economic restrictions, and sustainable natural resource management, plus creation of the information block for planning and management.

Development of the framework for the Amur River basin geo-information space determines the logical sequence for its creation. A layer-by-layer composition for the base geographic and base thematic (natural-geographic and economic-geographic)

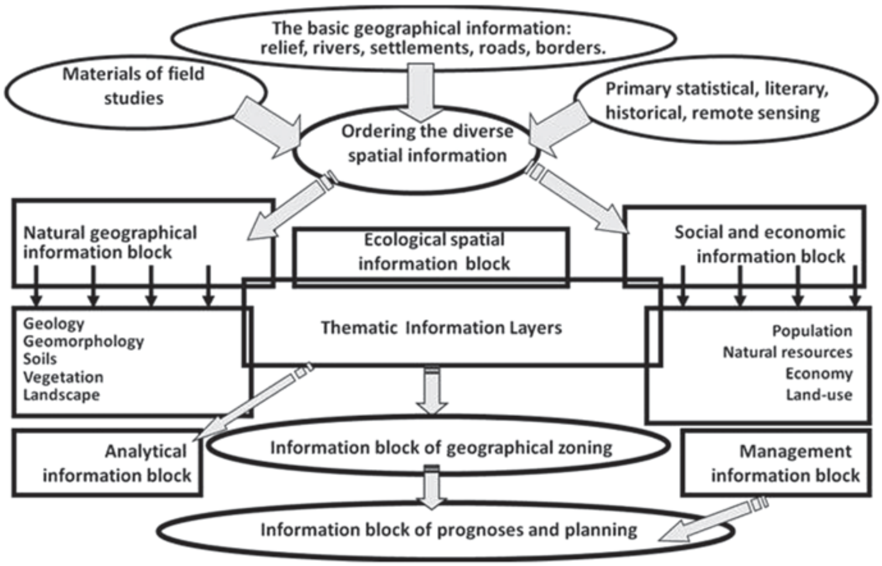


Fig. 7.2 Block schematic diagram of GIS support of geo-ecological studies in the Amur River Basin

blocks was determined. Some parameters for additional thematic blocks and certain management blocks were also determined. Each block included several information layers (Fig. 7.2).

A specially created digital grid relief model served as a basis for coordination and unification of the geographic and thematic information layers. Coordination of the layers took place in a specific sequence and, in this case, the preceding components were invariants for subsequent ones, for example: digital earth model—river networks—contour relief—road networks—boundaries; digital earth model—river networks—vegetation; and others. Unified layers for the transboundary territories were constructed by successive solution of methodological, technological, and practical problems and spatial adjustment of the digital layers based on the layer invariants (Yermoshin et al. 2007).

7.3 Creation of Electronic Layers and Maps for the Amur River Basin

Base geographic, base thematic, and certain additional thematic blocks have been created for the entire Amur River Basin. The layers were built from printed maps, with correction by remote sensing data. Raw maps were scanned, digitized, and reduced to common standards, projections, and scales. These were then transformed into common layers. All electronic layers presented in this paper were constructed using ArcInfo, ArcView, and ArcGIS at scale 1:2.5 million, and were consistently and spatially coordinated. Semantic data were summarized in appropriate attributive tables.

7.3.1 Base Geographic Block

The base geographic block contains the following layers:

- Relief with contour lines at 100, 200, 300, 400, 500, 600, 800, 1000, 1500, 2000, and 2500 m
- Hydrologic network: main rivers and channels, tributaries, lakes, reservoirs, channels
- Settlements: centers of state, regional, and local government; cities with populations more than 1 million, 1 million to 500,000, 500,000 to 100,000, and 100,000 to 10,000
- Road networks: railways, highways, and other hard-surface roads
- Borders: state, regional, and local

A digital 3D relief model was built from Shuttle Radar Topographic Mission (SRTM) data with steps of 8 arc s (250 m). Data accuracy is 90 m horizontally and 20 m vertically (National Center for Earth-surface Dynamics 2007). Vector maps at scale 1:1,000,000 for Russia and China, distributed by the USA National Geospatial-Intelligence Agency, were initial data for the main coverage (National Geospatial-Intelligence Agency 2005). Coordination and adjustment of basic parameters was done with 1:1,000,000 and 1:500,000 topographic maps and remote sensing images. Data of settlements and roads in the Chinese part of the basin were additionally corrected in accord with the National Economic Atlas of China (Wu 1994).

7.3.2 Base Thematic Layers

The thematic information layers are the information base of the geo-information space, and many of them were compiled for the entire Amur River Basin for the first time during this project. The thematic layers were constructed from printed maps with correction by remote sensing (Landsat TM+) data (USGS 2013).

7.3.2.1 Geologic Structure

This layer (Fig. 7.3) was based on the “Geological map of Pri-Amurye and adjacent territories at scale 1:2,500,000,” printed in 1999, and “The Geological map at scale 1:3,000,000 from the Atlas of the Mongolian People’s Republic” (Krasny and Peng 2000).

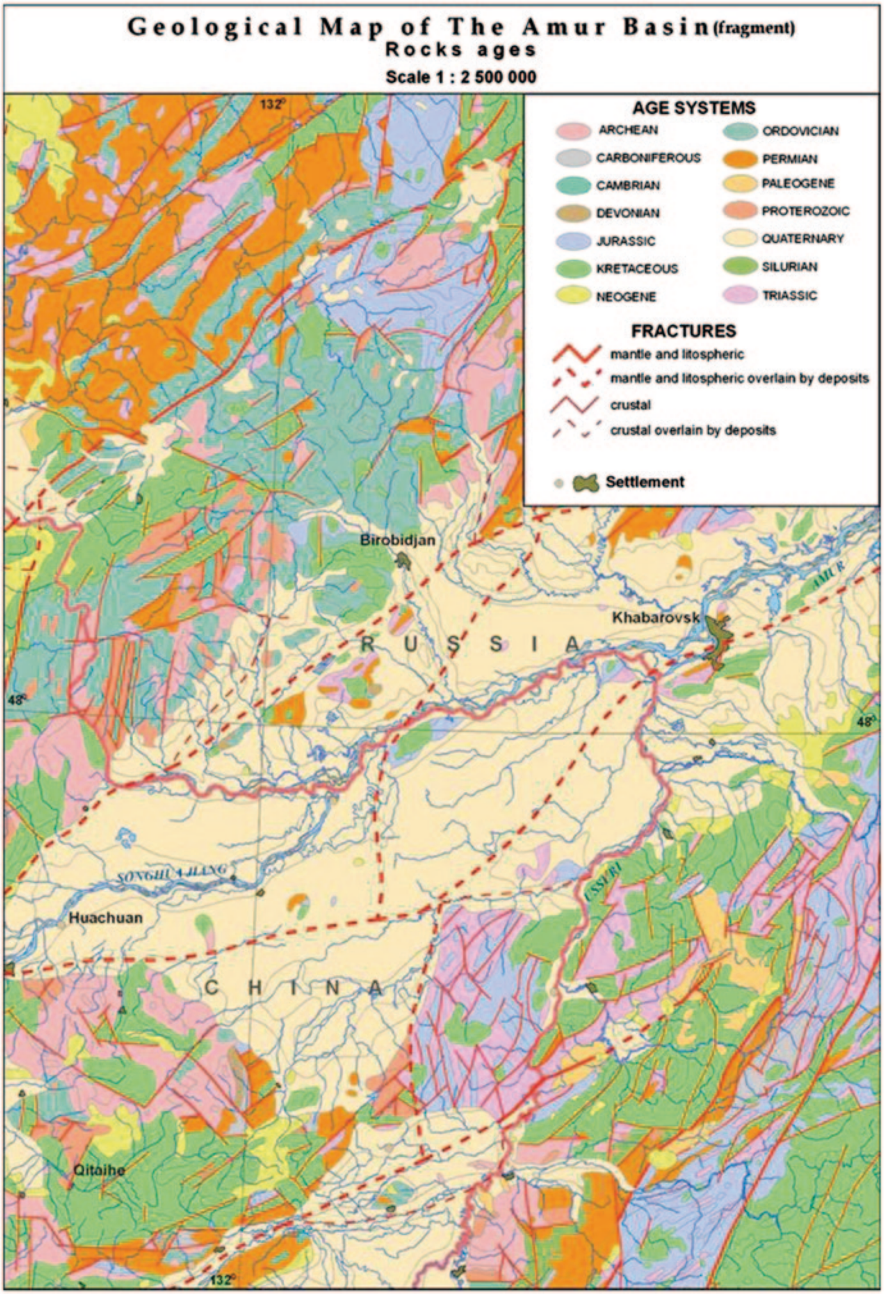


Fig. 7.3 Geologic map of the Amur River Basin, with rock ages and fractures

Geologic bodies are mapped at scale 1:2,500,000. Each body is dated at the system level, and some at the section level. Rocks are classified by their composition into intrusive, volcanogenic, sedimentary, and metamorphic. Intrusive and volcanogenic rocks are categorized in greater detail. Thus, granites are divided into granitoids, diorites, gabbroids, ultrabasites, and alkaline categories, and some of these are divided even further, e.g., granitoids include granites, granodiorites, monzogranites, and granosyenites. Volcanogenic rocks are partitioned by composition into acidic, intermediate, basic, alkaline, and mixed. Tectonic fractures are segregated into mantle, lithosphere, and crust, which in turn are divided into covered and not covered by sedimentary strata (Krasny and Peng 2000).

7.3.2.2 Vegetation

Information sources for the vegetation maps were a 1:2,500,000 scale vegetation map of the Amur River Basin (Sochava 1968), a 1:3,000,000 vegetation map of Mongolia printed in 1990, and The Vegetation Atlas of China at 1:1,000,000 scale, printed in 1990 (The Mongolian People's Republic 1990b). Legends for these maps vary. A uniform legend reflecting the basic geographic distribution of vegetation within the basin was needed. It was also necessary to create a generalized map for the Chinese part of the basin. The legend developed by Sochava (1968) was taken as the basis for the vegetation maps in this project.

A group of associations, the main mapped units, was elevated to the level of a formation to unify the data. Vegetation was divided into plains associations and mountain associations during generalization for the Chinese part of the basin. Steppe vegetation was split into meadow and arid steppes. This is permissible because steppes remain as small islands among tracts of cultivated land on the plains, and sod-cereal steppes are mainly at altitudes over 500 m above sea level. Agricultural lands are indicated by one symbol across the entire territory. In the Mongolian part of the Amur River Basin, agriculture is not well developed at all, and pastures occupy a very small area. This way of displaying agricultural land allows one to see the degree of cultivation.

The vegetation map shows a variety of modern vegetative communities and their distributions. These distributions reflect zonal (on plains) and height-zonal (in mountains) change of vegetative cover over this extensive territory, with its complex combination of natural conditions. The legend includes 69 vegetation types describing forests, meadows, steppes, bogs, shrub thickets, and agricultural lands of the plains and mountains in the basin (Yermoshin et al. 2007).

Table 7.2 details certain vegetation spatial distributions for the Amur River Basin. Only vegetation types with the largest portions are described in Table 7.2; therefore, the total is less than 100 %.

Larch forests cover the largest area, approximately 22 % in the mountains and 10 % on the plains. Shrubs of various kinds are found in valleys and plains, covering about 10 % of the territory. Steppe vegetation is concentrated in the western part of the Amur Basin. Arid and meadow steppes cover almost 13 % of the territory. Cedar and broadleaf forests are a very important part of the landscape. These are mainly

Table 7.2 Spatial distribution of vegetation in the Amur River Basin

Class	Type	Area (103 km^2 percent)	
Forest and shrubs of plain and plateau	Larch	202	9.9
	Broad-leaved	89	4.3
	Small-leaved	58	2.9
	Shrubs	47	2.3
Vegetation of river valley	Shrubs	155	7.5
	Grass/damp grass	58	2.8
	Swamp	36	1.8
Steppe	Meadow steppe	152	7.4
	Arid steppe	108	5.3
Forest of mountain	Larch	451	22.0
	Dark coniferous	100	4.9
	Cedar/cedar broad leaved	56	2.7
	Broad-leaved	95	4.6
	Small-leaved	86	4.2
Agricultural land		275	13.4

on low to mid elevation mountains and occupy 7.3 % of the basin. Agricultural land occupies more than 13 % of the territory.

7.3.2.3 Dominant Soils

This layer is based on Russian, Mongolian, and Chinese soil maps. These maps were compiled over the years by members of different soil science schools and at varying scales (Baklanov and Ganzei 2004; Soil Cover and Soils of Mongolia 1984; Kovda and Lobova 1971, 1975; Kovda 1959; Kovda and Lobova 1975; Program of the Soil Map of USSR 1972; The Soil Atlas of China 1986; USSR Academy of Science 1962). During compilation of the dominant soils layer, source map data was preserved to the fullest extent possible. For the Russian and Mongolian parts of the Amur River Basin, these data were coded on soil mapping polygons and added directly to the database. For northeastern China, the soil mapping polygons underwent multistage generalization with respect to the specific character of the region to create some uniformity. Then, the data were coded and added to the database. The scale for this layer is 1:2,500,000.

The legend for the dominant soils layer took into consideration differences between national soil classifications and nomenclatures of the source soil maps. The legend of the Russian source map (Fridland 1988) includes two nomenclatures—one that was used when the map was compiled in 1977 (Classification and Diagnostics of Soils of USSR 1977) and a previous one (Ivanova and Rozov 1967). To avoid terminology difficulties, we used soil names from the Russian source map (Fridland 1988) for the “English Name” section of the legend and retained soil nomenclatures of the other source maps. Soil names for the Mongolian part of the basin generally coincided with the Russian soil names but included a few outdated names that were omitted in later soil classifications (Shishov et al. 1997, 2004).

Soil names in the Chinese part of the Amur River Basin were diverse. Many Chinese soil names correspond to Russian ones, and these were preserved in our legend (e.g., chernozem, chestnut, grey forest, and others). Some Chinese soil classifications do not correspond to Russian ones, but have possible correlates among Russian soils. In the legend of the dominant soils layer, the names of such soils are given in parentheses and substituted by their Russian correlates (e.g., brown earth). In a few cases, the soil names were unofficial, traditional names. Such names were correlated with names of the Chinese soil classification, and their possible (partial) correlates were found in the Russian soil classification and substituted for these. The official and traditional Chinese soil names are given in parentheses (e.g., chernozem-like). Mountainous soils also found on the plains are not listed in the "Soils of Mountainous Regions" section of the legend. This section includes only soils that are not found in the piedmonts and plains of the Amur River Basin (Petergburgsky and Rode 1967; Rozanov 1974a, b).

Soil nomenclature of the dominant soils layer legend for the Amur River Basin is correlated with global soil nomenclature (Stolbovoi and Sheremet 1995). This correlation is based on the literature (Stolbovoi and Sheremet 1995, 2000; Lozet and Mathieu 1998) and electronic resource data (FAO Major Soils of the World 2002). The diverse soils of the basin are grouped in the legend by landscape and geographic zoning used in the source soil maps from Russia in 1972, Mongolia, and China. These are soils of: tundra, taiga and coniferous-broadleaf forest, broadleaf forest and wooded steppe; steppe; and dry steppe. Hydromorphic, saline, alluvial, anthropogenic, and mountainous soils are also included. Table length constraints permit only part of the legend to be included here (Table 7.3).

The complex and diverse soil cover of the Amur River Basin results from contrasting natural conditions (climate, relief, vegetation, parent material) within the territory. The Amur River Basin lies within two soil-bioclimatic belts, boreal and sub-boreal, shown in Soil and Geographical Zoning of USSR in 1962, and its soil cover reflects those bioclimatic conditions. When describing soil type, we use English soil names to fully preserve their informative value. In our opinion, these names reflect the complex and diverse nature of the regional soil cover better than the generalized FAO-UNESCO and WRB nomenclatures (Stolbovoi and Sheremet 2000). The target map scale and character of the geographic distribution allowed preservation of the soil mapping polygons from the source soil maps (Fridland 1988; Soil Cover and Soils of Mongolia1984) at the levels of soil type, sub-type, genus, and taxonomic type. The English soil names reflect this low-level taxonomic division. The FAO-UNESCO and WRB nomenclatures deal with higher taxonomic levels and cannot fully reflect the diversity and specific distribution of soils in the study region. If necessary, the legend permits easy correlation between the English names and those of FAO-UNESCO and WRB. The western Amur River Basin is in the Mongol-Manjur sub-boreal steppe region (Rozov and Stroganova 1979), which includes areas of Russia, China, and Mongolia. This area is characterized by highly complex soil cover and specific soil formation conditions.

Table 7.4 describes spatial distributions of dominant soils, whose total area exceeds 3 %. Cambisols have the greatest extent in the Amur River Basin. Cambisols are 20 % of broadleaf forest and wooded steppe soils, and 18 % of taiga and conifer-

Table 7.3 Soil map legend for the Amur River Basin. (Fragmentary)

Soil code	Soil name		
	Name in English	Name in the revised legend of the soil map of the World FAO-UNESCO, 1990	Name in the world reference base for soil resources, 1998
Soils of Tundra			
1	Podburs light tundra	Gelic Podzols (PZi)	Cryosols Haplic (CRha)
2	Podburs tundra (without subdivision)	Ferric Podzols (PZf)	
Soils of Taiga and soils of coniferous and broad-leaved forests			
3	Gleyzems weak-gley peaty-humic taiga	Gelic Gleysols (GLi)	Cryosols Histic (CRhi)
4	Gleyzems peaty-muck taiga		
5	Taiga peaty-muck high-humic non-gleyic	Gelic Cambisols (CMi)	
6	Podzolics, mostly shallow podzolics	Dystric Podzoluvisols (PDd)	Albeluvisols Haplic (ABha)
7	Podzolic-gleys peat and peaty	Gleyic Podzoluvisols (PDg)	Albeluvisols Histic (ABhi)
9	Sod-pale-podzolics and podzolised brownzems	Eutric Podzoluvisols (PDe)	Albeluvisols Umbric (ABum)
10	Podzolised brownzems (Beijang bleached)		
11	Sod-pale-podzolics and podzolised brownzems deep-gleyic and gley	Gleyic Podzoluvisols (PDg)	Albeluvisols Gleyic (ABgl)
12	Podzolised brownzems meadow (Beijang bleached meadow)		
13	Podzolised brownzems gley (Beijang bleached gley)		
15	Podzols humic-illuvial	Haplic Podzols (PZh)	Podzols Carbic (PZcb)
16	Podzols illuvial-humic-ferrugenous (without subdivision)		Podzols Haplic (PZha)
17	Podzols dry-peaty		Podzols Histic (PZhi)
18	Podzols gley peaty and peat, mostly humic-illuvial	Gleyic Podzols (PZg)	Podzols Gleyic (PZgl)
20	Podburs taiga (without subdivision)	Cambic Podzols (PZb)	Podzols Entic (PZet)
21	Podburs dry-peaty		Podzols Histic (PZhi)
22	Podburs ochric		Podzols Rustic (PZrs)
23	Brownzems raw-humic illuvial-humic	Dystric Cambisols (CMd)	Cambisols Dystric (CMdy)
24	Brownzems raw-humic		
25	Brownzems raw-humic gley	Gleyic Cambisols (CMg)	Cambisols Gleyic (CMgl)
Soils of broad-leaved forests and wooded steppe			
34	Brownzems acid	Dystric Cambisols (CMd)	Cambisols Dystric (CMdy)
35	Brownzems acid podzolised		

Table 7.3 (continued)

Soil code	Soil name		
	Name in English	Name in the revised legend of the soil map of the World FAO-UNESCO, 1990	Name in the world reference base for soil resources, 1998
36	Brownzems weakly-unsaturated (brown earths)	Eutric Cambisols (CMe)	Cambisols Eutric (CMeu)
37	Brownzems weakly-unsaturated podzolised		
38	Brownzems gleyic and gley	Gleyic Cambisols (CMg)	Cambisols Gleyic (CMgl)
39	Dark brownzems	Eutric Cambisols (CMe)	Umbrisols Haplic (UMha)
40	Dark brownzems grayed	Dystric Cambisols (CMd)	

Table 7.4 Spatial distribution of soils in the Amur River Basin

Class	Type	Area (103 km^2 percent)	
Soils of taiga and coniferous broad-leaved forests	Haplic Podzols	118	5.8
	Dystric and Gleyic Cambisols	308	18.0
Soils of broad-leaved forests and wooded steppe	Eutric and Dystric Cambisols	417	20.5
Soils of steppe	Haplic Phaeozems	63	3.1
	Calcic Kastanozems	75	3.7
Hydromorphic soils	Umbric and Mollic Gleysols	186	9.1
	Fibric and Terric Histosols	135	6.6
Alluvial and marshy soils	Fluvisols	69	3.4

ous broadleaf forest soils. Hydromorphic soils are also common; gleysoils make up more than 9% and histosols more than 6.5% of the basin.

7.3.2.4 Geomorphology

This layer is very important for landscape mapping and serves as the morphological information base. The legend and map use the following classifications: high mountain, middle mountain, high plateau, low mountain, plateau, hill mountain, hill, plain, depression, and valley (Fig. 7.4).

Delimitation of specified morphological relief types was performed in an interactive mode in ArcGIS 9.3. Data sources for geomorphologic mapping were the Digital Earth Model and scanned topographic maps (Advanced Spaceborne Thermal Emission and Reflection Radiometer 2004) with scales from 1:1,000,000 to 1:200,000, depending upon complexity of the relief. Key parameters of the classifications are described in Table 7.5. Most of the basin is low mountain (42%) and middle mountain (17.2%). High plateau, hill mountain, hill, plain, depression, and valley morphologies occupy approximately equal areas in a range 5–7.4% of the area of Amur River Basin.

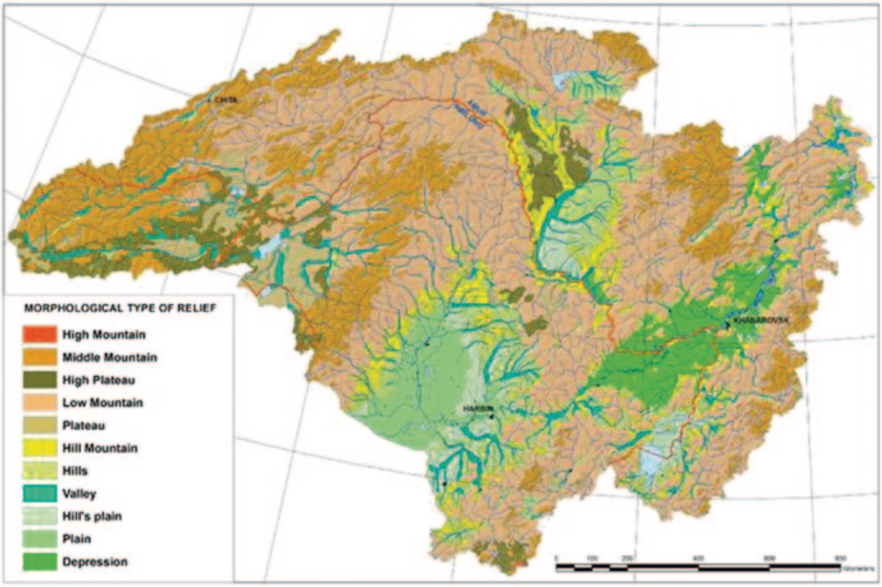


Fig. 7.4 Geomorphology zoning map of the Amur River Basin

Table 7.5 Spatial distribution of geomorphologic zones for the Amur River Basin

Type	Altitude (m)	Slope incline (degree)	Area (103 km^2%)	
High mountain	More than 1800	15–45	0.8	0.1
Middle mountain	850–1800	12–25	361.5	17.7
High plateau	600–1500	5–12	100.4	4.9
Low mountain	300–900	10–20	861.6	42.1
Plateau	300–900	2–5	79.1	3.9
Hill mountain	200–400	4–10	122.7	6.1
Hills	100–300	2–5	152.3	7.5
Plain	50–300	0–3	140.6	6.9
Depression	0–150	0–1	101.0	5.0
Valley	0–200, 400–800	0–2	117.8	5.8

7.3.3 Additional Thematic Layers

7.3.3.1 Modern Land Use

Images from LANDSAT TM+ (USGS 2013) obtained during 2000–2001 served as baseline information for this electronic layer. A resolution of 30–100 m was used for a majority of the composite layers. Thirty-meter resolution was excessive for the final scale of 1:2,500,000; therefore, the resolution was changed to 50–150 m for some basin areas. For some of the most questionable blocks, images with 15–30 m

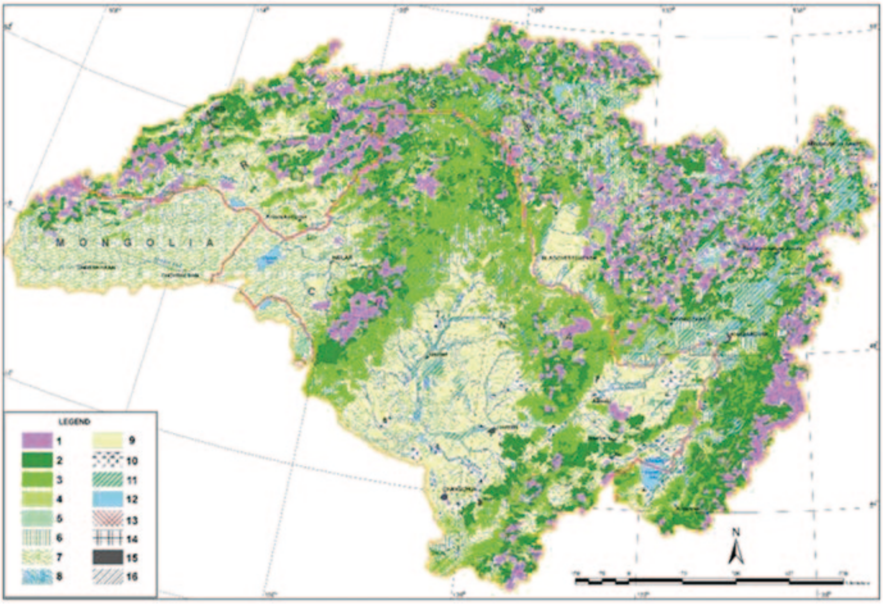


Fig. 7.5 Land-use map of the Amur River Basin for year 2000 (according to decoded satellite images). *1* Coniferous forest, *2* mixed forest, *3* deciduous forest, *4* sparse forest, *5* other forest land, *6* scrub, *7* grassland, *8* mountain tundra, *9* dry land, *10* paddy field, *11* wetland, *12* lake and reserve, *13* slash fire, *14* forest cutting area, *15* urban land, *16* unused land

resolution were used. Interpretation was done using ArcView 3.3 with Image Analysis software and subsequent conversion into ArcInfo files. The vegetation index was calculated from vegetation maps in electronic raster form and their vector analogs (The The National Atlas 1990a; Sochava 1968; The Vegetation Atlas of China 2001), numerous topographic maps at scale 1:500,000, and satellite images, in order to improve identification objectivity.

The following categories of modern land use were identified: wooded land, meadows and shrubs, agricultural land, water objects, and other land (Fig. 7.5). Categories in turn were subdivided into types of modern land uses that populated the information cells. Because the mapping scale was fine and the generalization level high, each type may have included different kinds of use and natural states. The genesis of each type of land was not considered, because it could be formed in a number of ways (Ganzey et al. 2007).

Wooded lands include coniferous, mixed, deciduous and sparse forests, and other forest land. Coniferous forests were further categorized into spruce, fir, Korean pine, pine, and larch plus their varieties. Mixed forests included all transitional varieties from coniferous to deciduous forests, in approximately equal percentages. Deciduous forests included broadleaf and small-leaved forests and their varieties. Sparse forests were categorized as discontinuous forests of varying composition or alternating forests and shrubs with crop density less than 30%. Other forest land

Table 7.6 Land use and % shares in Amur Basin from small-scale satellite image interpretation

Type of land use	Area (km^2)	China (%)	Russia (%)	Mongolia (%)	PRC (%)
Coniferous forests	277,561.1	13.5	77.1	3.0	19.9
Mixed forests	347,319.5	16.9	66.5	1.8	31.7
Deciduous forests	316,195.3	15.4	37.4	1.0	61.6
Sparse forests	145,447.4	7.2	73.1	3.2	23.7
Burned areas	27,051.8	1.3	97.1	1.8	1.1
Other forest lands	5421.1		Not specified	41.1	58.9
Grassland	257,233.1	12.7	9.5	54.7	35.8
Shrubs	121,697.9	6.0	67.7	4.7	27.6
Reclaimed lands	25,982.0		9.1	Not specified	90.9
Agricultural lands/ irrigated lands	347,487.0	18.3/1.3	23.3	0.7	76.0
Lakes	10,619.4	0.5	48.9	7.7	43.5
Reservoirs	2493.0	0.1	81.9	Not specified	18.1
Wetlands	140,018.6	6.9	68.1	0.1	31.8
Large settlements	2666.3	0.1	37.2	Population less than 100 thousand people	62.8
Unused lands	657.0	0.0	93.0	Not specified	7.0
Shrubs with high-mountain tundra	13,328.4	0.8	96.1	1.0	2.9
Wastelands	222.8	0.0	83.6	Not specified	16.4
Felled forest	8655.1	0.4	77.7	Not specified	22.3

included commercial plantings. Meadows and shrubs consist of shrubs, meadows, and shrubs with high-mountain tundra. Shrubs were further partitioned into shrubby, meadow-shrubby, and shrubby sparse forest land where shrub vegetation is prevalent. Meadows include any grass vegetation such as proper meadows, steppes, and others. Shrubs with high-mountain tundra include dwarf Siberian pine, dwarf forms of high-mountain shrubs, and tundra.

Agricultural lands included rice fields and plowed lands. Water objects embraced lakes, reservoirs, and wetlands. Wetlands were further divided into types of bogs—raised, pigweeds, and others—as well as floodplain meadows and marshes. Other lands included burned areas and logged forests, lands allotted for settlement (large settlements), industrial and unused lands (quarries, dumps, and others) (Table 7.6).

Natural and climatic conditions in the Amur River Basin vary considerably. Table 7.2 describes vegetation zones in the region. Climatic conditions vary from arid to perhumid. This variation determines the natural diversity of land resources in the basin, which have been subjected to intense economic development for the last 125 years (Baklanov and Ganzei 2004). Forest lands occupy 54.3 % of basin territory, of which 16.9 % is mixed forests, 15.4 % deciduous, and 13.5 % coniferous. Sparse forests and burned-out and destroyed forests occupy 7.2 and 1.3 %, respectively. Grasslands and shrubs occupy 18.6 % of the basin. Agricultural lands take up a similar area, 18.3 %, including 1.3 % that are irrigated lands. The share of wetlands is high, at 6.9 %.

As detailed in Table 7.6, the majority of coniferous and mixed forests are in the Russian part of the basin, whereas deciduous forests predominate in Chinese territory. Most wetlands and shrubs are in Russian territory as well. The Chinese part of the basin is characterized by higher economic development, as demonstrated by the fact that 76 % of agricultural lands are in this part. More than 97 % of the destroyed and burned-out forests, about 78 % of logged forests, and more than 73 % of sparse forests are in Russian territory. These data reflect the unfavorable Russian forest exploitation policies of the 1990s.

A comparison of the compiled map with a published map of Amur River Basin vegetation (Sochava 1968) shows a simplification of forest structures toward low-value forests. This is especially true in the Russian and Chinese parts of the northern Great Khingan and Little Khingan mountains, and northern parts of Sikhote Alin and the Chita Region. These changes result from active commercial logging in the Chinese part of the basin until the 1990s, continued logging in Russian territory, and yearly forest fires, particularly in the latter territory.

There was considerable growth in agricultural land in China during the 1990s and early 2000s. These changes concentrate on the Xiang Jiang plain and eastern foothills of the Great Khingan Mountains. The increase of such land reduced wetland and forest areas. The majority of wetlands are now in the Russian part of the basin (Amur Oblast, Jewish Autonomous Region, and Khabarovsk Krai).

Such significant differences of modern land use by the countries within the Amur River Basin result in acute transboundary environmental problems. Among these are decreasing biodiversity, disturbance of animal migration routes and fodder resources, fragmentation or destruction of habitat, increased fire and flood hazards, surface water contamination, and water and air pollution.

7.3.3.2 Land Use in the 1930s and 1940s

This layer reveals land use in the Amur River Basin during the 1930s and 1940s at scale 1:2,500,000. Topographic maps from the period and modern research were used as data sources (Himiyama et al. 1995, 2002). In all, we analyzed more than 1400 topographic sheets at different scales, published in different countries and in different languages (Russian, English, and Japanese). Total volume of the scanned map files exceeds 120 GB. These sources vary in detail and quality. Some of the main data sources are described in the following.

Maps compiled and produced during 1942–1957 in the USSR at 1:1,000,000 scale, with data from earlier, detailed surveys, cover the entire basin territory. The following categories of land are represented with varying degrees of confidence: forested areas, sparse forests, shrubs, bogs, non-forested areas, and large settlements. Maps compiled and produced early in the 1950s in the USSR at 1:300,000 scale cover fragments of the Russian part of the basin. The following categories of land are represented with varying degrees of confidence: forest, with some division into coniferous, deciduous, and mixed; sparse forests; shrubs; bogs; meadows; and settlements. Maps compiled and produced during 1949–1952 by the General Staff of the U.S. Air Force (in English) at 1:250,000 scale cover Manchuria. The following categories of land are portrayed: forest, bog, and settlement. Maps compiled and produced during 1942–1947 in the USSR (in Russian) at 1:200,000 scale cover parts of the Russian and Mongolian basin territories. The following categories of land are included with varying degrees of confidence: forest, with some division into coniferous, deciduous, and mixed; sparse forests; shrubs; bogs; meadows; and settlements.

Maps compiled during 1936–1938 by the General Staff of the Kwantung Army of Japan at 1:100,000 scale cover Manchuria. The following types of land are represented, in sufficient detail for developed lands and simplified for underdeveloped mountain lands: forest, with some division into coniferous, deciduous, and mixed; sparse forests; shrubs; bogs; meadows; settlements; and agricultural areas. Maps compiled and produced during 1938–1951 in the USSR at 1:100,000 scale cover border regions of the USSR. The following types of land are distinguished, in sufficient detail for developed lands and simplified for underdeveloped mountain lands: forest, with some distinction into coniferous, deciduous, and mixed; sparse forests; shrubs; bogs; meadows; settlements; and plowed land.

The Chinese part of the basin was mapped from the Japanese 1:100,000 scale maps and checked against the 1:250,000 scale topographic maps. For the forested border areas of China, topographic sheets produced in the USSR during the 1940s at scales from 1:100,000 to 1:1,000,000 were also used. The Mongolian part of the basin was characterized using topographic maps at 1:100,000, 1:200,000, and 1:1,000,000 scales produced in the USSR during the 1930s and 1940s. Some of the 1:200,000 scale maps were reissued during the 1950s, using data from 1:100,000 scale maps produced in the late 1930s and early 1940s. For the Russian part of the basin, maps at 1:100,000, 1:200,000, 1:300,000, and 1:1,000,000 scales were analyzed. Some maps at 1:100,000 and 1:300,000 scales were issued in the 1950s. Those maps were used only for underdeveloped mountain areas.

In the course of land-use analysis using these maps, the following problems arose:

- Discrepancies between maps of different scales and periods for the same area
- Differences of map contents when integrating along state boundaries
- Nonconformity of information on adjacent topographic sheets, especially regarding types of forest lands
- Nonconformity of basic structural elements (rivers and watersheds) as a result of poorly explored territory, especially in underdeveloped mountain areas
- Differences of map symbols in different countries
- Wide range of legend types for the Japanese maps (up to eight types)

These problems were resolved by multi-stage analysis of one territory with different sources, comparing the structure of base geographical elements with the present. For this, appropriate up-to-date maps and space images were used. Maps of the Russian and Mongolian parts of the basin were constructed by Soviet topographers using one method and legend, so differences in those maps are minor. Most problems arose from comparison of 1:100,000 and 1:200,000 scale maps issued in the USSR and Japan. The Soviet topographic maps have less detail, but their legends

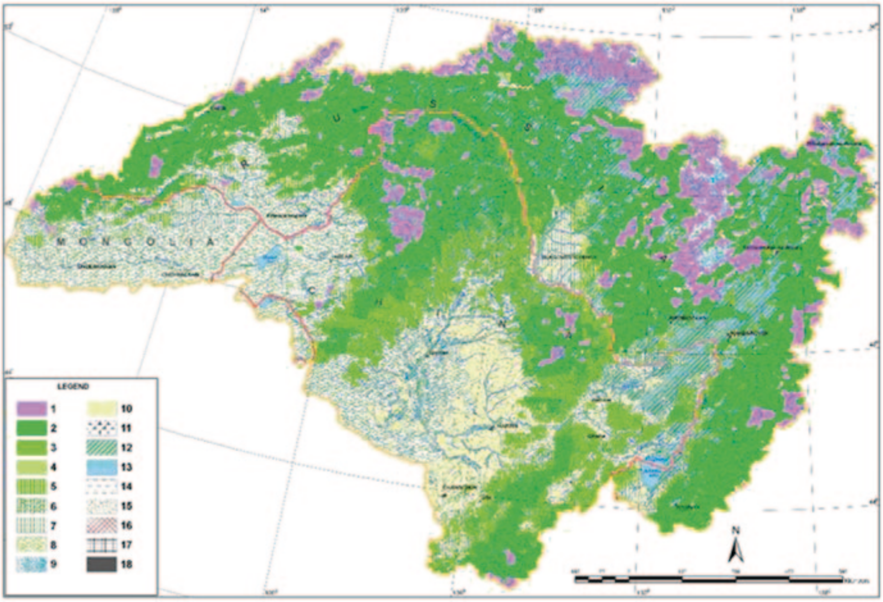


Fig. 7.6 Land-use map of the Amur River Basin for the 1930s and 1940s. *1* Coniferous forest, *2* mixed forest, *3* deciduous forest, *4* sparse forest, *5* shrub and sparse forest, *6* shrub and grassland, *7* shrub, *8* grassland, *9* mountain tundra, *10* dry land, *11* paddy field, *12* wetland, *13* lake, *14* salt marsh, *15* sand, *16* burned area, *17* felled forest, *18* urban land

are unified. Therefore, when constructing a uniform map of the entire basin, a number of Japanese mapping units were generalized.

In the resulting uniform map, the following categories of land are represented with varying degrees of confidence: forests, separated into coniferous, mixed, deciduous, burned area, and felled; sparse forests; sparse forests and shrubs; shrubs and grassland; grassland; wetland; salt marshes; mountain tundra; agricultural lands, divided into dry lands and paddy fields; lakes and reservoirs; sands; and urban lands (Fig. 7.6).

Land use in the 1930s and 1940s within the countries in the basin is characterized in Table 7.7.

The 1930s and 1940s land-use layer was then created using GIS programs ArcView 3.3 and ArcGIS 9.1. ArcInfo data were created from the topology. Tables of attributive properties were constructed, in which typological information and digital coding were reflected. In accord with the resulting scale (1:2,500,000), objects of areas greater than 40 km^2 (2×3 mm on the map) and linear objects with widths greater than 2.0 km (0.8 mm on the map) were depicted. For comparison, legends of the compiled maps were unified (Fig. 7.7).

Land-use situations within the Amur River Basin during 2000–2001 and 1930–1940 were analyzed, and estimated changes over the 70-year interval were given (Ganzey et al. 2010a, b). To analyze changes, land-use data were recalculated

Table 7.7 National features of land use in the Amur River Basin in 1930s and 1940s

Type of lands	Structure of basin land use (%)	Areas of types of lands (103 km^2)			Structure of land use (%)		
		Russia	China	Mongolia	Russia	China	Mongolia
Coniferous forests	9.3	155.6	30.8	3.0	15.4	3.6	1.8
Mixed forests	33.7	495.4	179.4	12.1	49.0	20.8	7.2
Deciduous forests	8.8	17.1	163.4	0.1	1.7	19.0	0.0
Sparse forests	1.3	14.8	7.9	3.0	1.5	0.9	1.8
Sparse forests and shrubs	3.2	31.6	20.5	12.3	3.1	2.4	7.3
Shrubs	2.0	28.0	0.1	12.0	2.8	0.0	7.1
Shrubs and grassland	1.4	5.9	22.3	0.7	0.6	2.6	0.4
Grassland and steppes	17.6	46.0	195.2	117.2	4.6	22.7	69.4
Dry lands	6.7	12.2	124.6	no	1.2	14.5	no
Paddy fields	0.0	no	0.5	no	no	0.1	no
Wetlands	13.3	155.9	111.2	3.2	15.4	12.9	1.9
Lakes and water reservoirs	0.4	5.6	2.9	0.6	0.5	0.3	0.3
Settlements	0.0	0.2	0.1	no	0.0	0.0	no
Felled forest	0.1	2.1	no	no	0.2	no	no
Burned areas	0.9	17.7	no	0.2	1.8	no	0.1
Mountain tundra	1.0	21.0	no	0.3	2.1	no	0.2
Salt marshes	0.2	1.0	0.3	3.8	0.1	0.0	2.3
Sands	0.1	no	2.0	0.3	no	0.2	0.2
Total	100.0	1010.1	861.2	168.8	100	100	100

in accord with the common unified legend. There were some essential changes over the 70-year period. There were negative trends for forest lands, grassland, wetlands, and mountain tundra, which decreased by 5.5, 5, 6.3, and 0.4 %, respectively. Sparse forests and shrubs increased slightly, while plowed lands increased considerably (by 11.3 %). The area of forests affected by logging grew by 6,000 km^2, while burned areas increased by 10,000 km^2.

In the Russian part of the basin, forest lands decreased, while sparse forests, shrubs, plowed lands, rice fields, logged areas, and burned areas increased. Forest lands decreased in Khabarovsk Krai and Zabaikalye Territory, but increased in Primorsky Krai and Amur Oblast. Plowed lands in Russian territory increased by nearly 69,000 km^2. The percentage decreased in Primorsky Krai and increased in Amur Oblast and Zabaikalye Territory.

The area of wetlands declined across the Russian part of the basin. However, against the background of total reduction, there was a redistribution of this type of land. Wetlands increased by 13.3 % in Khabarovsk Krai and decreased by 12.6 % in Amur Oblast. The areas of burned and felled forests increased significantly. Logged areas shifted to Khabarovsk Krai, where 50.6 % of felled forests in the Russian part of the basin were located. The area of burned-out forests in Zabaikalye Territory increased by 16.5 %. In the Chinese part of the basin, general trends of land-use change

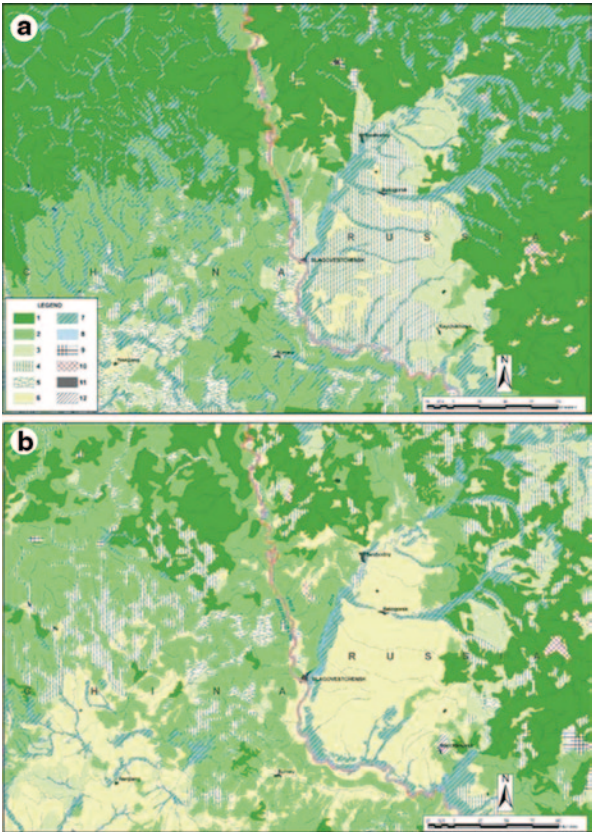


Fig. 7.7 Xioxing Anling and Zeya-Bureya plain. Forest and scrub land: **a** in 1930s and 1940s; **b** at the beginning of twenty-first century. *1* Coniferous forest, *2* deciduous forest, *3* sparse growth, *4* bush, *5* grassland, *6* dry land, *7* wetland, *8* lake, *9* forest cutting area, *10* slash fire,*11* urban land, *12* unused land

were related, on the one hand to decreases of forest lands, wetlands, and meadows and, on the other hand, to increases of plowed lands, rice fields, lakes and reservoirs, and settlements. Burned areas and felled forests increased 30.1 and 34.8 %, respectively. Sparse forests, shrubs, meadows, plowed land, rice fields, and wetlands decreased appreciably in Heilongjiang Province. In Jilin Province, rice fields and lakes and reservoirs increased 30.6 and 21 %, respectively. In the Mongolian part of the basin, there were slight increases in forest and plowed lands and a considerable increase in meadows. As in the other parts of the basin, wetlands decreased.

A key topic of this research is the question of land-use data reliability for the 1930s and 1940s and present day. In our opinion, a high level of confidence is only possible for general tendencies of land-use distribution in the Amur River Basin. Our analysis of land use in the basin since the 1930s confirmed the results of earlier research by Russian and other authors. Further, our data allow more detailed, uniform spatial analysis of land use for two periods in the basin, using previously unavailable information. New cartographic land-use data supplement earlier statistical and literary materials and thematic maps to form the basis of land-use investigation, not only within the limits of administrative territories but also across transboundary geosystems.

7.4 Conclusions

GeoInfoSp is essential for planning and implementing sustainable development and natural resource management. The layers and maps we created are an integral part the Amur River Basin geo-information space, which is an information base for analysis of past and future land-use/land-cover change and sustainable natural resource management in that transboundary basin. Our future research will involve two phases. The short-term plan is to finish landscape mapping for the entire basin, assess anthropogenic changes to the landscape, and construct a functional zoning map as an information base for planning sustainable natural resource management in the Russian part and entire basin. The long-term plan is to create an ecological information block and managerial informational block.

In a natural resource management project for any size territory, it is necessary to address every stage of acquisition and processing of spatial geo-information, from inventory to predictive-recommendatory. As projects are executed and information accumulated, completeness (density) of the geo-information space (i.e., number of information layers) and saturation of that space (i.e., number of characteristics of each layer) increase. Accordingly, time and expense for the first stages of execution of each subsequent project decrease. This is evident at specific regional and sub-regional levels where the entire, earlier studied territory is involved in each subsequent project, and nearly all information layers can be used. The transboundary Amur River Basin is an example of such a territory.

In further studies, it may be possible to aggregate all spatial data obtained during such projects on land use in the Amur River Basin into a unified geo-information space, with standard base layers. This will allow cross-spectrum analysis of various unified data at different scales, thereby facilitating a more accurate estimate of the state of natural resource management and planning of further improvements in the countries of the region. The conjugate thematic and topographic electronic information layers in a strictly defined geo-information space permit zonings of various types, functional zoning of territories with different hierarchical levels, and natural resource management for sustainable development.

References

Advanced Spaceborne Thermal Emission and Reflection Radiometer (2004) ASTER global digital elevation map. http://asterweb.jpl.nasa.gov/gdem.asp. Accessed 2007

Anuchin DN (1896) East Manchuria. Phys Geogr III–IV:149–157

Anuchin DN (1897) Manchuria. Phys Geogr I–II:101–127

Baklanov PYa, Ganzei SS (2004) Principal stages and tendencies of the land use development in Amur River basin. Geogr Nat Res 4:19–28

Baklanov PYa, Ganzei SS (2008) Transboundary territories: problems of sustainable nature management. Dalnauka, Vladivostok

Baklanov PYa, Ermoshin VV, Ganzey SS (2005) Problems of creation of GIS-support for the Amur river basin project. Report on Amur-Okhotsk project, Research Institute for Humanity and Nature, Kyoto, vol 3, pp 11–19

Baklanov PYa, Ermoshin VV, Krasnopeyev SM (2010) Regional geo-informational systems in the nature management in the Far East. Open Educ 5:12–23
Batuyev AR (2003) Cartographic application for regional development. Ph. D. Thesis of Geography. IGAN, Moscow
Cherkashin AK et al (2002) Geo-information system of territory management. Publication l (Institute of Geography). Siberian Branch of Russian Academy of Sciences, Irkutsk
Chinese Academy of Sciences (2001) The vegetation atlas of China. Scale 1:1,000,000. Science Press, Beijing
Classification and Diagnostics of Soils of USSR (1977) Kolos, Moscow
Ermoshin VV (2002) Functional zoning of territory based on the GIS-technologies. In: Cartographic and geoinformation support of the regional development management. Proceedings of VII scientific conference on the thematic cartography, Irkutsk, pp 86–89
Ermoshin VV (2004) The features of formation of geo-information space for nature conservation projects on transboundary territories. In: The XII scientific meeting of geographers of Siberia and the Far East, Pacific Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok, pp 155–157
Ermoshin VV, Baklanov PYa, Ganzey SS (2005) Problems and means of creation of GIS-support for the Amur River basin. In: Proceedings of international conference Intercarto-InterGIS11—sustainable development of territories, GIS theory and practical experience, Stavropol, Budapest, pp 131–136
FAO Major Soils of the World (2002) Land and water digital media series. CD-ROM. Rome
Fridland VM (1988) The soil map of the Russian Soviet Federative Socialist Republic Scale 1:2.5 M. VASHNIL. GUGK USSR, Moscow
Ganzey SS (2004) Transboundary geo-systems of the southern far East of Russia and North-Eastern China. Dalnauka, Vladivostok
Ganzey SS, Yermoshin VV, Mishina NV, Shiraiwa T (2007) Modern use of lands in the Amur river basin. Geogr Nat Res 2:17–25
Ganzey SS, Ermoshin VV, Mishina NV (2010a) Land cover/land use changes in Amur river basin in the XX century (Russia, China, Mongolia). Land-use and land-cover changes in the separate regions of the world (IGU—LUCC Atlas), vol 5, pp 5–15
Ganzey SS, Ermoshin VV, Mishina NV (2010b) The dynamics of land use within the Amur basin in the 20th century. Geogr Nat Res 31(1):18–24
Himiyama Y, Ito H, Kikuchi T, Honma T (1995) Land use in North-East China in the 1930. Report of the Taisetsuzan Institute of Science, vol 30, pp 25–35
Himiyama Y, Morishita Y, Arai Y (2002) The use of Japanese topographical maps of Northeast China at 1:50000 for the LUCC study. Report of the Taisetsuzan Institute of Science, vol 36, pp 107–114
Institute of Soil Science, Academia Sinica (1986) The soil atlas of China. Hseung Yi, Beijing
Ivanova EN, Rozov NN (1967) Guidelines for classification and diagnostics of soils. Kolos, Moscow
Kachur AN, Jin X, Baklanov PYa, Ganzei SS (2001) Diagnostic analysis of the Lake Khanka Basin (People's Pepublic of China and Russian Federation). UNEP/CRAES/PGI FEBRAS, Nairobi
Kanakubo T (1993) The selected main theoretical issues facing cartography. In: 16 Internernational cartographic conference proceedings, Cologne, vol 1, pp 17–25
Karakin VP, Sheingauz AS (2004) Land resources of Amur River basin. Bull FEB RAS 4:23–37
Korotky MF (1912) Essay of vegetation of the Zeisko-Bureinsky district, Amur Oblast. In: Proceedings of the Amur expedition, St. Petersburg, 16-3
Korytny LM (2001) Basin concept in the nature management. Institute of Geography, Siberian Branch of Russian Academy of Sciences, Irkutsk
Koshkarev AV, Antipov AN, Batuev AR, Ermoshin VV, Karakin VP (2008) Geo-portals as part of spatial data infrastructures: Russian Academy-supported resources and geoservices. Geogr Nat Res 29:18–27
Kovda VV (1959) Nature and soils of China (with The soil map of the People's Republic of China. Scale 1:10 M.). USSR Academy of Science Publishing House, Moscow

Kovda VA, Lobova EV (1971) The soil map of Asia (for FAO-UNESCO Soil Map of the World project). GUGK USSR, Moscow
Kovda VA, Lobova EV (1975) The soil map of the world. Scale 1:10 M. GUGK USSR, Moscow
Krasny LI, Peng Y (2000) Geological map of Pri-Amurye and adjacent territories (1996–1999). VSEGEI, Harbin. Blaboveschensk, St. Petersburg
Lozet J, Mathieu C (1998) Explanatory dictionary of soil science (in French). Mir, Moscow
Maak RK (2007) Travel to Amur at 1855. Reprint of 1859. SPB: Alfaret. 260.
Mitinsky AN (1911) Materials of position and needs of trade and industry in the Far East. In: Proceedings of the Amur expedition VIII, St. Petersburg
Narita H, Shiraiwa T, Nakatsuka T (2004) Research project plan. Report on Amur-Okhotsk Project 2, pp 1–24
National Center for Earth-surface Dynamics (2007) Shuttle Rader Topography Mission (SRTM). http://ftp://e0srp01u.ecs.nasa.gov/srtm/version1/. Accessed Feb 2000
National Geospatial-intelligence Agency (2005) NGA Raster Roam. http://geoengine.nima.mil/geospatial/SW_TOOLS/NIMAMUSE/webinter/rast_roam. Accessed 2005
Nikolskaya VV, Chichagov VP (1957) On joint researches of Chinese and Soviet geographers in the Amur River basin. Bulletin of the USSR. Acad Sci Ser Geogr 2:166–168
Obruchev VA (1952) Selected works on geography of Asia, vol 2. State Publishing House of Geography, Moscow, p 400
Petergburgsky AV, Rode AA (1967) English-Russian dictionary of soil science and agricultural chemistry. “Soviet Encyclopaedia” Publishing House, Moscow
Program of the Soil Map of USSR (1972) Soil map Scale 1:2.5 M. VASHNIL, Moscow
Przewalski NM (1947) Travel to Ussuri krai. 1867–1869. State Publishing House of Geography, Moscow, 310p
Rozanov BG (1974a) Soil nomenclature in Russian and foreign languages I. MGU, Moscow
Rozanov BG (1974b) Soil nomenclature in Russian and foreign languages II Comp. MGU, Moscow
Rozov NN, Stroganova MN (1979) Soil cover of the world. MGU, Moscow
Shiraiwa T (2010) Final report of the Amur Okhotsk project 2005–2009. Report on Amur-Okhotsk Project, vol 6, pp 3–20
Shishov LL, Tonkonogov VD, Lebedeva II (1997) Russian soil classification. Dokuchaev Soil Institute of Russian Academy of Agricultural Science, Moscow
Shishov LL, Tonkonogov VD, Lebedeva II, Gerasimova MI (2004) Classification and diagnostics of soils of Russia. Oikumena, Smolensk
Sochava VB (1968) Vegetation map of Amur River watershed Scale 1:2,500,000. The USSR Academy of Science
Soil Office of the Mongolian People’s Republic (1984) Soil cover and soils of Mongolia Scale 1:2.5 M. Nauka, Moscow
Stolbovoi VS, Sheremet BV (1995) A new soil map of Russia, compiled in FAO system. Pochvovedenie 2:149–158
Stolbovoi VS, Sheremet BV (2000) Correlation of legends of the soil map of the USSR at the Scale of 1:2.5 M and the FAO Soil Map of the World. Pochvovedenie 3:272–287
The Mongolian People’s Republic (1990a) The national atlas. Ulan Bator, Moscow
The Mongolian People’s Republic (1990b) The vegetation map, scale 1:3,000,000. The national atlas. Ulan Bator, Moscow
Tikunov VS (1991) Some theoretical problems of cartography. Geodesy Cartogr 7:27–31
Tikunov VS, Tsapuk DA (1999) Sustainable development of territories: cartographic-geo-informational support. SSU, Moscow
USGS (2013) USGS Global Visualization Viewer. http://glovis.usgs.gov
USSR Academy of Science (1962) Soil and geographical zoning of USSR. USSR Academy of Science
Venyukov MI (1970) Travel to Priamurye, China and Japan. Khabarovsk Publishing House, Khabarovsk, p 240
Wu H (1994) The national economic atlas of China. Oxford University Press, Hong Kong

Yermoshin VV (2003) Geo-information space of the sustainable land use. Interaction of society and environment under conditions of global and regional changes. In: Abstracts of reports of the international conference, Institute of Geography of RAS, Barnaul, 22–29 July, pp 139–141
Yermoshin VV (2006a) Geo-information space of the transboundary geo-system of the Amur River basin. In: International conference proceedings of problems of the sustainable use of transboundary territories. Pacific Institute of Geography, FEB of RAS, Vladivostok, pp 20–23
Yermoshin VV (2006b) On development of the concept of geo-information space in geography (geo-information space in nature management). Geographic studies in the far East. Results and prospects 2001–2005. Dalnauka, Vladivostok, pp 161–168
Yermoshin VV, Ganzey SS, Murzin AA, Mishina NV, Kudryavtzeva EP (2007) Creation of GIS for Amur River Basin: the basic geographical information. Report on Amur-Okhotsk Project, vol 4, 151–159 (Publishing House, Moscow)

Chapter 8
Characteristics of Irrigation and Drainage Development on the Sanjiang Plain: A Case Study of State Farms

Hong Park

Abstract The theme of this chapter is elucidating the overall characteristics of the rapid development of irrigation and drainage systems and paddy fields on the Sanjiang Plain. The Sanjiang Plain, formed by the confluence of the Amur River, Ussuri River and Songhua River, is one of the world's three largest stretches of wetland. Large-scale agricultural development on the Sanjiang Plain started in the twentieth century, at the end of the 1940s. Water conservation projects have always been the key component to agricultural development on the Sanjiang Plain. The entities involved in these projects were stratified: on the first stratum was a national project for comprehensive land development; on the second stratum was the Bureau of Agricultural Reclamation, which manages state farms, and its Agricultural Reclamation Administration branch; and on the third stratum were the laborers-turned-farmers. The existence of these stratified entities was a condition made necessary by the nature of this project, i.e., the development of a large wetland. Situated at a point where three major rivers meet, the Sanjiang Plain is a flood plain, and so major infrastructural development was required, thereby necessitating this national project for flood control. The unique position of the local government, which administers the political as well as the economic machinery of state farms, also contributed to the promotion of agricultural development. It was also the presence of the laborers-turned-farmers, who assumed a superior role and had the economic reserves to make this project successful that helped to stabilize rice production with an underground water irrigation system.

Keywords Irrigation • Drainage • State farm • Sanjiang plain

H. Park (✉)
Graduate School of Agriculture, Hokkaido University,
Kita 9, Nishi 9, Kita-ku, Sapporo 060-8589, Japan
e-mail: park@agecon.agr.hokudai.ac.jp

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_8

8.1 Characteristics in Paddy Field Development on the Sanjiang Plain

8.1.1 Orientation of the Sanjiang Plain in Heilongjiang Province

The total area of the Sanjiang Plain is 10.65 million ha. The plain is located around the intersection of three great rivers. Flooding is frequent, due to the low-lying, flat terrain and the narrow and winding riverbeds, which impedes the recession of the flood waters. The average elevation is 40–60 m above sea level. The 76% of the plain's total area which is situated to the north of the Wanda Mountains is known as the "Minor Sanjiang Plain," and has an elevation of only 34 m, the lowest elevation in Heilongjiang. These factors contribute to making construction for farmland water conservation a heavy and difficult task. Before the Second World War, most of the plain's area was undeveloped and unused. Public farms and army-run land reclamation farms were established one after the other beginning in the late 1940s. Such farms formed the basis for today's state farms and for initial farmland development on the Sanjiang Plain. There were 104 state farms (as of 2008) in Heilongjiang Province, of which 53 were on the Sanjiang Plain.

There were 3.46 million ha of farmland on the Sanjiang Plain in 2005 (among which state farms accounted for 1.45 million ha and ordinary agricultural areas accounted for 2.01 million ha) representing 30% of the total farmland (11.52 million ha) in the province. The total area of farmland used by state farms was 2.27 million ha, and 63.9% of that land was on the Sanjiang Plain.

The state farms, in contrast with ordinary agricultural areas, have independent administrative organizations, and these are divided into two levels. One level is the State Farm Bureau (previously located in Jiamusi, now in Harbin) and its (nine) agencies or branch bureaus. The other level is the farm. As a provincial-level unit, the Bureau is under the leadership of the Heilongjiang Provincial Government in terms of its personnel (with an independent financial plan, under the direct leadership of the Land Reclamation Bureau of the Ministry of Agriculture). The branch bureau is administered at the same level as a prefecture-level city, and the farm corresponds to the district. There are four branch bureaus in charge of the state farms and there are 53 farms on the Sanjiang Plain. On the other side, there are five prefecture-level cities and 23 counties in the ordinary agricultural areas.

8.1.2 Distribution of Paddy Fields on the Sanjiang Plain

In order to facilitate analysis on the characteristics of different areas we divide the Sanjiang Plain into regions in consideration of the distribution of state farms. There are four branch bureaus on the Sanjiang Plain. Please refer to Table 8.1 and Fig. 8.1 for the distribution of the relevant cities (districts) in these regions.

Table 8.1 Districts and cities in various on the Sanjiang plain. (Source: Park 2011)

State farm branch bureau	Number of cities/districts	Cities/districts
Baoquanling	4	Hegang city (Luobei district, Suibin district) Tangyuan district (under administration of Jiamusi city)
Hongxinglong	11	Jiamusi city (Huachuan district, Fujin district) Shuangyashan city (Jixian district, Youyi district, Baoqing district, Raohe district) Qitaihe city (Boli district)
Jiansanjiang	2	Tongjiang district, Fuyuan district (under administration of Jiamusi city)
Mudanjiang	4	Jixi city (Jidong district, Mishan district, Hulin district)

Fig. 8.1 Distribution of State farm branch bureau in Sanjiang plain

The first region is composed of the Baoquanling Branch Bureau's administrative district and the ordinary agricultural area around where the Amur River and Songhua River merge. Included in this region are Hegang City (its urban areas, Mengbei District and Suibin District) and Tangyuan District (under the administration of Jiamusi City). In this region, there were 0.3 million ha of farmland on state farms and 0.25 million ha in ordinary agricultural areas (based on the data of 2005), meaning that a total of 0.55 million ha was divided about equally between state farms and ordinary agricultural areas (Table 8.2).

The second region is made up of the Hongxinglong Branch Bureau's administrative district and its nearby ordinary agricultural area. Included in this region are Jiamusi City (its urban areas, Huachuan District, Huanan District and Fujin District), Shuangyashan City (its urban areas, Jixian District, Youyi District, Baoqing District and Raohe District) and Qitaihe City (its urban areas and Boli District). There were 1.61 million ha of farmland in this region. Most of the state farms lie along both banks of the Songhua River and on the south bank of the Naoli River, which floods quite often. Farmland in the ordinary agricultural area was 1.19 million ha, accounting for 73.9 % of the total farmland in this region. State farms' farmland was 0.42 million ha in area, and this was characterized by large-scale farms; the largest farm, Youyi Farm (92,085 ha) is situated in this region.

The third region is composed of the Jiansanjiang Branch Bureau's administrative district and its neighboring ordinary agricultural area. Included in this region are Tongjiang District and Fuyuan District (both under administration of Jiamusi City). This region is situated around the intersection of the Amur River and Ussuri River, and is almost surrounded by the Songhua River and Naoli River. This is an area with very poor soil quality. State farms accounted for 0.39 million ha of farmland and ordinary agricultural areas accounted for 0.24 million ha, with a total farmland of 0.63 million ha.

The fourth region is made up of the Mudanjiang Branch Bureau's administrative district and its nearby ordinary agricultural area. Included in this region is Jixi City (its urban areas, Jidong District, Mishan District and Hulin District), which is located in the basin of the Muling River, a tributary of the Ussuri River. There were 0.34 million ha of state-farm farmland and 0.33 million ha of farmland in the ordinary agricultural area, for a total of 0.67 million ha.

The total farmland of state farms in these four regions amounted to 1.45 million ha, and that in the ordinary agricultural areas was almost the same, at 2.01 million ha. The total of all farmland in all regions amounted to 3.46 million ha.

Comparing paddy field area, the state farms owned 0.68 million ha, which represented 47 %, or about half of the total farmland used by state farms, while in contrast, the paddy field area in the ordinary agricultural areas was 0.33 million ha, or only 16 % of the total farmland in these areas, a lower position in paddy field development. Therefore, it could be said that the main force in terms of paddy field development was the state farms. Looking at the percentages of paddy field in various regions, the highest rate of 44 % was in Mudanjiang region, followed by 42 % in Jiansanjiang, 28 % in Baoquanling, and 18 % in Hongxinglong. However, among state farms only, the highest rate was 62 % in Jiansanjiang Branch Bureau, followed

Table 8.2 Paddy field possession rates of various regions on the Sanjiang plain (Comparison between state farms and ordinary rural area 2005) (Unit: ha, %, number of farms/counties). (Source: Park 2011)

		Farmland area	Paddy field area	Average area for farm/county	Paddy field area and number of farms/counties					
					Average	~25	25~50	50~75	75~	Total
Baoquanling	Farms	297,212	97,560	7505	32.8	7	4	2		13
	Rural area	249,455	57,310	14,328	23.0	3	1			4
	Subtotal	546,667	154,870		28.3					
Hongxinglong	Farms	420,216	141,242	11,770	33.6	4	4	2	2	12
	Rural area	1,188,486	153,756	13,978	12.9	9	2			11
	Subtotal	1,608,702	294,998		18.3					
Jiansanjiang	Farms	393,897	245,732	16,382	62.4	2	2	7	4	15
	Rural area	235,662	17,466	8733	7.4	2				2
	Subtotal	629,559	263,198		41.8					
Mudanjiang	Farms	341,290	197,353	15,181	57.8	5	1	5	2	13
	Rural area	332,728	103,465	17,244	31.1	4	2			6
	Subtotal	674,018	300,818		44.6					
Sanjiang plain	Farms	1,452,615	681,887	12,866	46.9	18	11	16	8	53
	Rural area	2,006,331	331,997	14,435	16.5	18	5			23
	Subtotal	3,458,946	1,013,884		29.3					

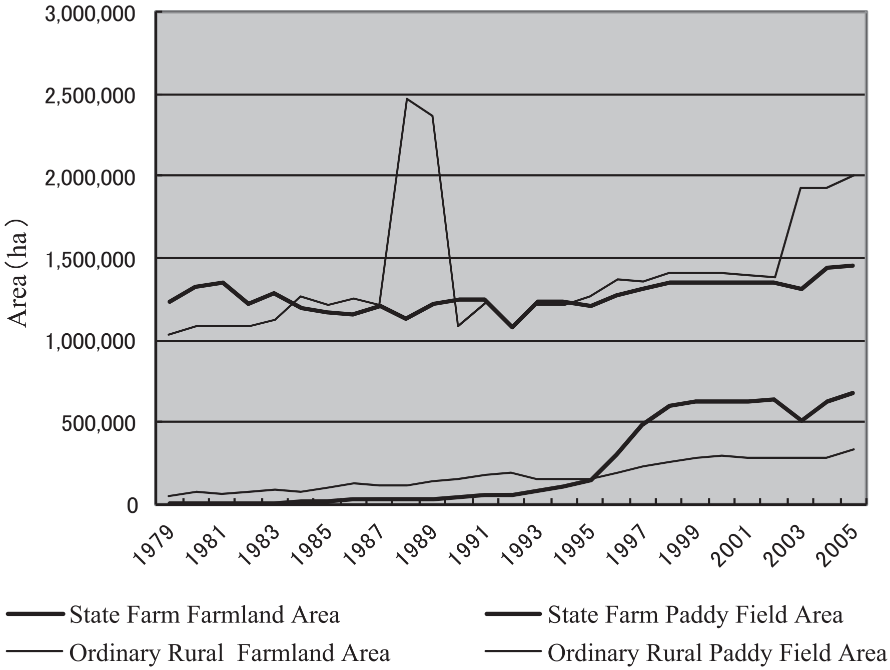


Fig. 8.2 Change of land utilization (Sanjiang plain). (Source: Park 2011)

by 58% in Mudanjiang, 34% in Hongxinglong, and 33% in Baoquanling. Four of the eight farms with farmland that was at least 75% paddy fields were in the Jiansanjiang region, and out of the 24 with farmland that was at least 50% paddy fields, eleven were in the Jiansanjiang region and seven were in the Mudanjiang region. This shows that the development of paddy fields in these two regions presented characteristics of large scale and high-degree concentration.

8.1.3 Development of Paddy Fields of State Farms and Ordinary Agricultural Areas

Figure 8.2 and Table 8.3 give a comparison of the change in paddy field area among state farms and ordinary agricultural areas from 1979 to 2005. First, in terms of the total farmland area (excluding the abnormal values in the 1980s with regard to ordinary agricultural areas) on the Sanjiang Plain, the total farmland area on state farms and in ordinary agricultural areas respectively changed slowly within the limits from 1 to 1.4 million ha (the figure for ordinary agricultural areas began to grow fast beginning in 2003). The paddy field area in ordinary agricultural areas increased from 0.05 million ha in 1979 to 0.33 million ha in 2005. The paddy field area on state farms increased from 0.01 million ha in 1979 to 0.05 million ha in the beginning of the

Table 8.3 Change of land utilization (Sanjiang plain) (Unit: ha). (Sources: "Statistical Yearbook of Heilongjiang Land Reclamation System 1978–1988", "Soaring Heilongjiang Land Reclamation System 1989–2000", "Statistical Yearbook of Heilongjiang Land Reclamation System"(various years), China statistics press)

Year	State farm farmland area	State farm paddy field area	Ordinary rural farmland area	Ordinary rural paddy field area
1979	1,230,500	7285	1,034,110	54,639
1980	1,321,948	8392	1,086,440	70,876
1981	1,352,747	6868	1,082,707	69,486
1982	1,222,740	7082	1,082,044	76,450
1983	1,283,947	9310	1,122,483	85,472
1984	1,200,640	12,436	1,272,730	78,329
1985	1,170,735	19,466	1,213,915	108,040
1986	1,163,078	28,852	1,252,853	130,678
1987	1,213,790	34,047	1,219,861	119,095
1988	1,129,752	29,187	2,475,333	116,697
1989	1,217,915	34,861	2,368,267	136,667
1990	1,246,369	46,473	1,084,792	154,917
1991	1,253,540	54,702	1,233,850	175,149
1992	1,084,652	62,901		188,104
1993	1,240,035	84,383	1,216,091	154,654
1994	1,235,787	104,426	1,221,326	147,918
1995	1,208,010	152,562	1,262,330	153,194
1996	1,280,675	304,246	1,372,473	194,575
1997	1,310,418	479,722	1,352,098	234,980
1998	1,356,113	600,108	1,408,330	252,964
1999	1,346,630	631,886	1,415,594	289,330
2000	1,350,407	620,372	1,406,891	297,143
2001	1,354,822	623,138	1,397,638	288,158
2002	1,355,922	643,790	1,388,473	287,453
2003	1,319,217	504,173	1,931,178	288,916
2004	1,441,130	631,515	1,931,178	288,916
2005	1,452,615	681,887	2,006,331	331,997

1990s, growing to about the same size as what was present in the ordinary agricultural areas at the beginning of paddy field development. The growth rate of the paddy field area increased rapidly during the 4 years from 1995 to 1998 (99 % in 1996), resulting in a sudden growth from 0.10 to 0.66 million ha. After that period, rice prices began to drop, and the growth rate turned negative in 2003. The paddy field area began to increase again beginning in 2004, and reached 0.81 million ha in 2006.

Next, we will look at the difference between ordinary agricultural areas and state farms in each of the four regions, first turning to the Baoquanling region.

The total farmland area was 0.30 million ha on state farms and was about 0.20 million ha in ordinary agricultural areas in 1980. In terms of paddy field area only, there were 0.02 million ha in ordinary agricultural areas in the 1980s, which increased to 0.04 million ha in 1990 and reached 0.05 million ha, or a paddy field percentage of 23 %, in 2005. On the other hand, there were only 3000 ha or paddy field area on state farms in 1980. This increased to 0.01 million ha in 1987, but dry farmland was still dominant. However, action was taken to speed up the growth of paddy field area beginning in 1994, as a result, the paddy field area on state farms began to exceed that of ordinary agricultural areas, growing abruptly to 0.1 million ha, the maximum value, in 2001. It began to decrease slightly afterwards, but later rose again to reach 0.10 million ha (a 33 % paddy field percentage) in 2005. This trend was consistent with the trend of the Sanjiang Plain as a whole.

Second, we will look at the Hongxinglong region. There were 1.60 million ha of farmland in this region in 2005, representing half of the farmland area on the Sanjiang Plain, and the percentage of this land that was in ordinary agricultural areas was rather high. Farmland development began very early here. There were 0.6 million ha of farmland area in the ordinary agricultural areas and 0.4 million ha on state farms in the early 1980s. The farmland area on state farms remained stagnant. On the other hand, the farmland area in ordinary agricultural areas reached 0.8 million ha at the end of the 1990s, and increased to 1.2 million ha in 2005. The paddy field area in ordinary agricultural areas developed on a large scale around Huachuan District, while the state farms began to develop their paddy fields at the end of the 1980s, so that it reached 0.08 million ha, its highest value, in 1992, decreasing after that until 1995, when it began to increase continuously to an area of 0.13 million ha in 2005. The paddy field area on state farms up to 1994 was still at the same level as that in ordinary agricultural areas in the 1980s. The paddy field area on state farms began to increase in 1995 and reached 0.13 million ha in 1997, higher than the area in ordinary agricultural areas. The paddy field percentage in ordinary agricultural areas was 13 %, and dry farmland was dominant. The paddy field percentage was 34 % on state farms, about at the same level as in the Baoquanling region.

Third, we turn to Jiansanjiang region, where many state farms are situated. The farmland area on state farms increased from the original 0.3 to 0.4 million ha gradually, while there were only 0.1 million ha of farmland area in ordinary agricultural areas up to 2002, and although this is expected to exceed 0.2 million ha in a few years, it is still in a process of further development. The soil condition is so poor in this region that it is hard to build any paddy fields in the ordinary agricultural area, and in fact, the paddy field area decreased by 0.02 million ha in 2005. The paddy field percentage was also very low, at only 7 %. The situation was different for state farms, by which great efforts were made to develop paddy fields in the mid-1990s, causing the paddy field area to increase from 0.05 million ha in 1995 to 0.2 million ha in 1999. It was this region that saw the fastest and highest growth. The paddy field area decreased a little bit following 1999, and then increased to 0.25 million ha in 2005 and to 0.33 million ha in 2006. Jiansanjiang is the only region in which paddy field development is still in progress. Its paddy field percentage was 62 % in 2005, the highest of the four regions.

The fourth region we will look at is Mudanjiang. Here, state farms and ordinary agricultural areas have about the same farmland area. The farmland area on state farms remained around 0.3 million ha for quite some time, but has increased to 0.34 million ha in recent years. The farmland area in ordinary agricultural areas has increased slowly from 0.20 to 0.33 million ha in recent years, bringing them to about the same level as state farms. In the 1980s, the paddy field area increased from 0.02 to 0.04 million ha in ordinary agricultural areas. Following this, it began to increase again at the end of the 1990s, and reached 0.1 million ha in 2005, with a paddy field percentage of 31 %, the highest among the four regions. The paddy field area on state farms was only 0.04 million ha in 1995, increased rapidly to 0.16 million ha after 3 years' development, and reached a record high of 0.2 million ha in 2002. The paddy field area then decreased to 0.17 million ha, but increased to 0.22 million ha in 2006. The paddy field percentage was 58 %, second only to the Jiansanjiang region, and is still increasing now.

As mentioned above, the dry land cultivation rate was very high upstream in the northeast part of the Sanjiang Plain, where the Baoquanling and Hongxinglong regions are situated. The paddy field percentage on state farms stayed stagnant at around 30 % for some years, reaching the lowest point in 2003. Now it has been restored to its maximum (Fig. 8.2). In contrast, the Jiansanjiang and Mudanjiang regions are in the process of farmland development downstream in the southwest, with paddy field development forming the central focus of their efforts. Their paddy field percentages are 62 % and 58 %, respectively, which is relatively high. Paddy field development in the two regions can be regarded as a major means of flood drainage in the two regions. The paddy field percentage in ordinary agricultural areas in the Jiansanjiang region was very low as it is very difficult to maintain paddy fields there, and the region faces some serious problems with the farm household economy. The region with the highest paddy field percentage was Mudanjiang.

8.2 Development of Water Conservation and Implementation Body

8.2.1 Regional Features of Water Conservancy Development

Next, the year 2000 is taken as our example to show the achievements in water conservation, the development and use of water resources, and the use of water in agriculture.

First, in terms of water conservation projects as a whole (Table 8.4), the Sanjiang Plain overwhelmingly had the best showing. In embankment construction for flood control, the Hongxinglong region, which is the largest in area, made the largest contribution. In water logging control, the Jiansanjiang region, which is situated near the intersection of the Amur and Ussuri rivers and has the lowest elevation, did the most work. All of the regions made similar efforts in irrigation. The rate of reservoir construction was quite low, this was due to the terrain of the Sanjiang Plain.

In the development and use of water resources, the Sanjiang Plain enjoyed absolute advantages. Motor-driven well irrigation accounted for 76.6 % (Table 8.5) of all irrigation methods, followed by water extraction from rivers, water diversion from rivers, and water storage works, in sequence. The Jiansanjiang region, in particular,

Table 8.4 Water conservancy development in state farms (2000). (Source: Park 2011)

	Embankment		Waterlogging control		Irrigation		Reservoir	
	Qty	L (km)	Qty	Area (kha)	Qty	Area (ha)	Qty	Catchment area (km^2)
Total in Heilongjiang State Farm	222	2875	159	2870	174	531,073	162	7492
Sanjiang plain	178	2509	136	2570	129	464,193	78	3655
Baoquanling	55	628	36	363	27	110,065	7	63
Hongxinglong	71	1146	37	599	41	143,828	40	1651
Jiansanjiang	7	172	33	1001	16	126,124	3	66
Mudanjiang	45	563	30	607	45	84,176	28	1875

Table 8.5 Development and utilization of water resources by state farms (1999) (Unit: million m^3). (Source: Park 2011)

	Total	Agriculture	Motor well pumped water	Water extracted from rivers	Water diverted from rivers	Water storage works	Rate of motor well irrigation
Total in Heilongjiang State Farm	5309	5236	3476	489	980	290	66.4
Sanjiang plain	4475	4419	3383	443	351	241	76.6
Baoquanling	786	776	678	23	52	22	87.4
Hongxinglong	1280	1253	855	215	44	139	68.2
Jiansanjiang	1205	1200	1195	4	-	0	99.6
Mudanjiang	1203	1190	655	201	255	80	55.0

used well irrigation almost exclusively. Table 8.6 shows the change in the quantity of newly dug water wells from 1993 to 2006. The number of wells was roughly in proportion to the developed paddy field area in the above-mentioned regions. A huge amount of investment was made in 1996, but with the retrogression of the paddy field area in 2003, almost no new wells were dug.

Irrigation zones had to be established when water was diverted from reservoirs or rivers or extracted from rivers. There were eight irrigation zones that had at least an area of 0.02 million ha, one irrigation zone with an area of between 6700 ha and 0.02 million ha, and 34 irrigation zones with an area of between 667 and 6700 ha on state farms. There were only 43 irrigation zones in total. The total irrigated area was 0.14 million ha (18.3 % of the total area of 0.74 million ha) on state farms, including two irrigation zones with a combined area of 0.01 million ha (11.3 % of the total area of 0.1 million ha) in the Baoquanling region, 15 irrigation zones with a combined area of 0.04 million ha (25.5 % of the total area of 0.14 million ha) in the Hongxinglong region, two irrigation zones with a combined area of 8000 ha (3.2 % of the total area of 0.25 million ha) in the Jiansanjiang region, and seven irrigation zones with a combined area of 0.04 million ha (20.7 % of the total area of 0.2 million ha) in the Mudanjiang region.

It is worth mentioning that in well irrigation zones, water conservation management was carried out by the agricultural households themselves.

Table 8.6 Change of quantity of newly dug wells (Unit: No. of wells). (Source: Park 2011)

Year	Total in Heilongjiang state farm	Baoquan-ling	Hongxin-glong	Jiansanji-ang	Mudanji-ang	Sanjiang Plain	Including: motor wells
1993	783	150	79	472	82	783	47
1994	510	229	126	56	99	510	147
1995	4540	1393	1467	1305	375	4540	0
1996	12,867	2010	3528	3003	3755	12,296	67
1997	8922	1587	1569	2717	2693	8566	0
1998	6959	830	1704	2020	2354	6908	25
1999	3948	1453	1318	1067		3838	280
2000	1471	543	536	132	240	1451	70
2001	1408	417	310	66	563	1356	277
2002	1464	62	105	230	785	1182	521
2003	21		21			21	0
2005	2759	323	567	1647	217	2754	334
2006	3123	382	147	2283	1	2813	1018

Table 8.7 Trend of investment in water conservancy in state farms (Unit: 10,000 yuan). (Source: Park 2011)

Year	Total	Irrigation	Reservoir	Waterlog-ging control	Embankment and dam	Others
1991	11,728	2676	1239	5709	1157	945
1992	14,499	3464	1463	6369	2087	1109
1993	15,025	2024	1171	7123	1567	3138
1994	14,341	1333	723	7785	2240	2259
1995	23,047	6031	547	9742	3365	3359
1996	28,007	10,053	393	13,150	2102	2307
1997	31,823	8836	774	14,432	2447	5331
1998	45,589	8002	762	21,931	7337	8292
1999	57,823	13,012	2894	16,429	16,588	8899
2001	52,975	13,165	4541	17,496	9602	8170
2002	52,063	15,779	3004	16,875	9001	7402
2003	52,716	25,011	3680	11,197	7156	5670
2005	44,514	20,277	2549	11,394	2673	7620
2006	41,908	19,910	1060	11,769	289	8879
Accumula-tive total	647,857	188,056	37,648	251,058	81,901	89,192

8.2.2 *Trends of Investment in Water Conservation Projects*

Before we look at the financial sources of investment in various water conservation projects, we need to understand the general trend of investment in water conservation projects from the view of engineering investment. Table 8.7 shows the trends of investment in water conservation projects by state farms in Heilongjiang Province over a relatively long term.

The amount of investment made in water conservation in the early 1990s was only 100 million yuan. It then increased rapidly from in 1995 and reached a record high of 580 million yuan in 1999, followed by a decrease afterwards. Investment in water logging control accounted for the highest rate before 2000 and began to decrease after 2000. Its position was taken over by investment in irrigation, which now stands at 200 million yuan, accounting for almost half of the total investment in water conservation. The sequence of priority for investment in water conservation projects since the 1980s has been embankment construction, water logging control, and irrigation, showing a conversion of focus from flood control and water logging control to irrigation projects.

8.2.3 Financial Sources for Development of Water Conservation Projects

Table 8.8 gives an overview of the projects and sources of funds for investment in water conservation projects in Heilongjiang. The total amount of such investment reached 2.36 billion yuan in 2005. This was composed of 1.23 billion yuan from state capital construction investment, which accounted for nearly 50 %, 663.66 million yuan, or 28 %, from medium-scale investment, and 396.85 million yuan from small-scale investment and water conservation management fees, at 17 % of the total.

Capital investment (I) was state investment in water conservation capital construction with a focus on embankment construction, flood control, and water logging control. The Grade-A Land Reclamation Observation and Design Institute was responsible for the design[1], which had to be reviewed by the Heilongjiang Department of Water Resources and approved by the Ministry of Water Resources. The amount of investment was 417.04 million yuan from the Central Government, 372.28 million yuan from the province and prefectures and 442.8 million yuan from the counties and state farms. The expenses borne by the province and prefectures were not the major portion of the investment, and were used only to build embankments and reservoirs, and for irrigation and drinking water projects. Excluding expenses for reservoirs, which were mainly borne by prefecture-level cities (e.g. Harbin, 270.95 million yuan, bank loans), investment was equally shared by the state and local administrations (counties or farms). Embankment construction was paid out of the Central Government's budget (Special Fund for Water Conservation) and treasury bonds, and borne by local governments. The operating expenses for irrigation and drinking water projects were bone by treasury bonds and local governments.

The objects of medium-scale investment (II) were "small-scale" water conservation projects relying on small-volume water conservation grants (Grant for Small-Scale Farmland Water Conservation Construction). The total amount was 219.96 million yuan under joint management by the State Farm Bureau, its branch bureaus, the departments of finance, and departments of water conserva-

[1] With regard to funds, please refer to the Compilation Com-mittee for Land Reclamation and Water Conservation Annals of Heilongjiang Province (2006) p. 617.

Table 8.8 Programs and sources of funds for investment in water conservancy (Heilongjiang 2005) (Unit: 10,000 yuan). (Source: Park 2011)

Scale	Category	Source of budget	Total	Direct operation by county	Irrigation	Waterlogging control	Water supply	Quality improvement and drinking water	Soil and water conservation	Reservoir	Embankment and dams	Small hydropower plant	Others	Including labor cost
I	Capital construction I	State	11,342	10,102						300	10,300	440	302	
	Capital construction II	Treasury bonds	30,362	800	10,700			7600	1562	500	7793		2207	
	Capital construction III	Province	5643	979	622			700		3002		400	919	
	Capital construction IV	Prefecture-level city loan	31,585							27,095	4490			
	Subtotal		78,932		11,322			8300	1562	30,897	22,583	840	3428	
	Burden of counties and farms	Local	44,280	7077	10,048			8921	737	5799	15,242	1533	2000	
	Total		123,212		21,370			17,221	2299	36,696	37,825	2373	5428	
II	Medium-scale investment	Local	21,996		15,338	1560		770	1190	345	130	102	2560	
	Agricultural development fund	Central	14,058		4625	3066	600	2002	190	1426	1243		905	
	Work-relief	Central	10,970		3840	445		6385		300				
	Local finance	Province	8586		4130	13	70	572	149	220	1609	1061	761	96
	Local water conservancy construction fund	Local	8256	1530	526	105			40	1421	1627	2000	2537	95
	Central water conservancy construction fund	Central	2500	360	30	100				840	750		780	
	Total		66,366		28,489	5289	670	9729	1569	4552	5359	3163	7543	191

Table 8.8 (continued)

Scale	Category	Source of budget	Total	Direct operation by county	Irriga-tion	Water-logging control	Water supply	Quality improve-ment and drinking water	Soil and water conser-vation	Reser-voir	Embank-ment and dams	Small hydro-power plant	Others	Includ-ing labor cost
III	Water conser-vancy business fee	Local	14,740	1968	75	45				1449	2406		10,765	7919
	Water conser-vancy charge	Farmers	19,186	11,046	2634	105	4744					108	11,594	8113
	Water resource charge	Farmers	5759	1900		8							5751	691
	Total		39,685		2709	158	4744			1449	2406	108	28,110	16,723
Others			6986		3258	1901	500	668	254	5	27		370	30
Grand total			236,253	35,762	55,829	7349	5914	27,618	4122	42,703	45,617	5644	41,454	16,945
IV	Self-raised funds by people	Farmers	13,820		4818	849	1	3583	1450	2033	477		607	
	Labor conversion	Farmers	9068		2490	1042	120	747	2752	890	897		129	
	Total		22,888		7308	1891	121	4330	4202	2923	1374		736	

tion for farms. In addition to state investment, the Agricultural Development Fund at 140.58 million yuan, the Work-Relief Fund at 109.7 million yuan, and other special funds also contributed to investment. Included in local financial sources were 85.86 million yuan from the provincial financial department and 82.56 million yuan from the Local Fund for Water Conservation Construction. Local counties and farms did not bear any of the expenses for this type of project. The funds were mainly used in irrigation, with 284.89 million yuan invested in this area, drinking water improvement projects mainly with funding from the Work-Relief Fund, construction of embankments and dams mainly supported by local capital, and water logging control supported by development funds.

In small-scale investment (III) and water conservation management, the local governments were responsible for bearing in 147.4 million yuan and farmers for bearing 249.45 million yuan (in water conservation charges and water resource charges). The ratio of the farmers' burden was relatively high. In investment projects, "others" (181.1 million yuan) accounted for 71 %, of which 60 % was labor costs. This shows that most of the investment went to management expenses in the irrigation zones.

With regard to the total amount of capital for each purpose, 558.29 million yuan went to irrigation, 456.17 million yuan went to embankment and dam construction, and 427.03 million yuan went to reservoir construction. A large percentage of all capital went to irrigation, as it had a comparatively large share of medium-scale investment (42.9 %). In addition, 138.2 million yuan was raised by farmers and 90.68 million yuan came from labor conversion, accounting for 10 % of the total investment in water conservation projects, with a large portion of this going toward irrigation[2].

Table 8.9 shows that among water conservation investment in the province, 15 % (360.29 million yuan) came from state farms, 14 % from the Central Government and 11 % from local sources. Among the funds from the Central Government, the Agricultural Development Fund accounted for 43 %. Among local capital, small-scale investment accounted for 45 %. Local investment accounted for 30 % of capital construction investments. These three items represented 81 % of the total investment. In local financial sources, self-owned capital was 132.46 million yuan, accounting for 37 %. Among financial sources from the land reclamation system, 237.83 million yuan was invested in the Sanjiang Plain, representing 66 % of the total investment by this system, and showing that investment in water conservation was concentrated on the Sanjiang Plain. On basis of the above-mentioned financial sources, together with consideration of the funds raised by the farmers, the burden on the state farms and farmers (inclusive of water conservation charges) is calculated as follows: in the whole land reclamation system, the state farms' burden was 32 % and famers' burden was 17 %. On the Sanjiang Plain, the state farms' burden was 41 % and the famers' burden was 21 %. The total burden of state farms and farmers was 49 % over the entire land reclamation system, but was 60 % in the Sanjiang Plain. This clearly shows that state farms and farmers on the Sanjiang Plain bore a very heavy burden.

[2] Analysis on the development of paddy fields by farming households and its role in rice production from a more detailed view, please refer to Park and Sakashita (1999); Park et al. (2001); Sakashita and Park (2004) and Park et al. (2009a, b).

Table 8.9 Sources of funds for investment in water conservancy (state farms 2005) (Unit: 10,000 yuan). (Source: Park 2011)

		Whole province	Capital construction	Direct operation by the province	State farm data	
					State farm	Sanjiang plain
Investment from the central government	Central government's budget	11,342	11,342	10,102		
	Work-relief	10,970		0	1402	0
	Central water conservancy construction fund	2500		360	500	430
	Special governmental fund (treasury bonds)	30,362	30,362	800	3807	2035
	Agricultural development fund	14,058		0	6039	3610
	Subtotal	72,197	41,704	11,262	10,346	6075
Local investment	Provincial budget	5643	5643	979		
	Bank loans	31,585	31,585	0		
	Local governmental fund	8586		0		
	Water conservancy business fee	14,740		1968		
	Local water conservancy construction fund	8256	2000	1530		
	Water conservancy charge	19,186		11,046	2326	1528
	Small-scale water conservancy programs	21,996		0	9990	4293
	Local burden	44,280	41,292	7077	13,246	11,828
	Water resource charge	5759		1900	121	59
	Others	6986		0		
	Subtotal	164,056	80,520	24,500	25,683	17,708
Total		236,253	122,324	35,762	36,029	23,783
	Self-raised funds by people	13,820			4474	4474
	Labor conversion	9068				

Table 8.10 shows the changes in investment in irrigation by state farms. The total amount of expenses for irrigation projects increased rapidly from 60.31 million yuan in 1995 to 163.96 million yuan in 1999 and then remained stagnant for some time before reaching 250 million yuan in 2002. Looking at the sources of capital, we find that the state capital accounted for about 60 %, and the agricultural development fund was a part of this. The ratio of medium-scale investment began to rise in 1999. Farms' burden fluctuated with the changes in the ratio of capital construction investment, and accounted for more than 30 % continuously after 2000.

Table 8.10 Change of financial resources of investment in irrigation (state farms, 1995–2005) (Unit: 10,000 yuan). (Source: Park 2011)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005
Treasury bonds	80			800	1260	610	1240	4915	900	1990
Water conservancy construction fund				600				2135	3259	30
Agricultural development fund	1323	2905	1681	1730	1565	1766	1433	2587	3520	2334
Work-relief	294	1358		935	486	200			80	420
Water conservancy development fund		2256	2077	2856	3333	1912		60		
Medium-scale investment	286	455	359	517	2325	3939	5906	6656	5085	7159
Interest-bearing loan	103		1200		2400	2095	420			
Subtotal	2086	6974	5317	7438	11,369	10,522	8999	16,353	12,844	11,933
Farms' burden	1417	2435	2106	119	1027	1872	6173	7877	6585	4597
Water resource charge			31	32						
Water conservancy charge		632		414	816	771	606	781	828	791
Famers households' burden		340	2905	3185	3164	92	92	0	0	2588
Subtotal		972	2936	3631	3980	863	698	781	828	3379
Total	6031	10,383	11,741	11,187	16,376	13,257	15,871	25,011	20,257	19,910
Ratio of burdens of the state to province	34.6	67.2	45.3	66.5	69.4	79.4	56.7	65.4	63.4	59.9
Ratio of farms' burden	23.5	23.5	17.9	1.1	6.3	14.1	38.9	31.5	32.5	23.1
Ratio of farmer housholds' burden		9.4	25.0	32.5	24.3	6.5	4.4	3.1	4.1	17.0

Table 8.11 Change of employee households' income and expenditure in cash (Unit: yuan). (Source: "Statistical Yearbook of Heilongjiang Land Reclamation System" (various years), compiled by China statistics press)

Year	Income from production	Expenditure in production	Land rent
1996	2291	1697	1024
1997	3279	2040	780
1998	2463	1197	322
1999	785	977	662
2000	1190	1180	365
2001	1864	366	464
2002	2133	1179	715
2003	7577	3405	2306
2004	8574	4100	2064
2005	8797	5760	2283
2006	11,007	6116	2329

Farmers not only were responsible directly for engineering costs, but also for water conservation charges. Due to incomplete statistics, some factors were excluded from the present calculation, but as a whole, farming households were responsible for about 30 million yuan each year. Based on this assumption, the burden on farming households was about 25 %.

In other words, the local burden for water conservation investment, including maintenance and overhead after completion of the facilities, exceeded 50 %, and the locally raised capital was a greater contributor than state investment. Among local burden, the farmers' burden was increasing. This was realized through the collection of ever-growing "land rent" from farming households. Table 8.11 shows the sales volume in cash, expenditures for production, and land rent levels of farming households. The sales volume and expenditures for production per capita increased sharply from 2002 and the land rent became higher too, but remained at about 2000 yuan. However, in consideration of the fact that the land rent was paid from the balance of sales volume less production costs, the level was relatively high.

Below, we will look at X state farm as an example to carefully clarify the process of paddy field development on state farms and by laborers-turned-farmers.

8.3 A Case Study of X State Farm

8.3.1 Present Stage of Paddy Field Development

X State Farm is a medium-sized state farm with a total area of 26,760 ha, including farmable rice paddy acreage of 10,987 ha (2006). On X Farm, there are 36 Production Groups (No. 1–36) which are subordinate organizations. Production Group No. 17, which we selected as the object of this study, is an average sized Production Group (PG) composed of 65 households with a cultivated acreage of 662.9 ha.

While irrigation development on X Farm began on a full scale in 1985 with well irrigation, further irrigation development in PG No. 17 started in 1993, 10 years later.

PG No. 17 is located in the southeast corner of the State Farm, and until 1990, its irrigation source was mainly the Songhua River. However, in 1991, irrigation from the river was suspended, and since then the dam has mainly performed drainage functions instead of irrigation. Reasons for the change were largely due to the difficulty in pumping water, as there was a lack of water supply from the river, and incidents of repeated flooding during the rainy season.

A groundwater well irrigation system was planned for implementation after 1992, and the PG worked on a well-digging project in 1992 and 1993.

With the construction of groundwater wells, many areas rapidly switched to rice farming. In 1994, out of 673.7 ha, 552.6 ha had been converted to rice farming fields. The 121.1 ha left along the rivers were lent to the surrounding villages as field farms, since conditions in these areas were unsuitable for rice farming. PG No. 17 has specialized in rice farming since 1994.

During this Period, there were 65 households, with an average of 8.5 ha of land each. There were 70 groundwater wells, and each groundwater well irrigated 7.9 ha of farmland, with an average of one groundwater well per household. The actual distribution of state farmlands were less than 5 ha for 9 households, 5–7.5 ha for 19 households, 7.5–10 ha for 18 households, 10–12.5 ha for 11 households, 12.5–15 ha for 4 households, and more than 15 ha for 4 households. The number of farmers within different operation scales will be illustrated later. The 37 households with 5–10 ha of farmland, which was well suited to the capacity of the groundwater wells, accounted for 57 % of the total number of households, mean while, very small-scale and large-scale households also irrigated with groundwater wells.

In addition, in 2003, PG No. 17 was selected as a production area by XM Ltd., a trading firm, and over 90 % of the area was cultivated as specified by contract. During the production process, PG No. 17 was required to follow all the instructions given by XM Ltd. with regard to the species, fertilizers, pesticides, etc. that were used. The top officials in the Production Group were one chief, one secretary, two assistant chiefs (one of them would do the statistics), one accountant, and three technicians.

The responsibilities of the Production Group changed greatly following the adoption of the "Liangfeizili" policies in 1999. These policies stated that farmers were to be responsible for both production and living expenses. Because of this, the Production Group was not involved in transporting production resources to farmers' yards, guaranteeing funding, or adjustments for crop rotation during the field crop era; instead, they concentrated on farm policies, transmission of orders and collecting money by deputy.

8.3.2 History and Features of Paddy Field Development

In the following section, we look at the history of paddy field development, which involves a look into case studies among the farmers.

Up until 1982, all farms were under government management and the Zhi Gong (staff and workers on the farms) were mere farm laborers. In 1983, the contract system, already used in ordinary agricultural areas, was introduced on the state farms, because of which the laborers became farmers (farming households). At this point, the number of laborers-turned-farmers totaled 86, with a cultivated acreage of 483.1 ha. Of this area, 400 ha were dry fields and only 83.1 ha were paddy fields.

Paddy field development can be divided into two periods: the incentive measures to switch from dry fields to paddy fields from 1985, and the planned full-scale switch to rice farming in 1993. During that time, special attention was given to "invited farmers", farmers from areas outside of the state farm that had know-how in rice farming. PG No. 17 welcomed invited farmers proactively beginning in 1989. In the first year, only six households joined, and after that, 3–5 households joined every year. Things stabilized for this farm after the latter part of the 1990s, until the "invited farmers' policy" was finally terminated in 2001. Currently, out of the 65 households in PG No. 17, there are 22 that were originally laborers, while the remaining 43 households are invited farmers.

From 1985, there was a push to switch to rice farming, but the increase of paddy farming areas was limited, mainly because of such factors as cultivation techniques, varieties of rice, and low rice prices. Among the case studies, three households developed paddy fields during this period. In case No. 2 in 1985, four farmers who were already present on the land took over an area of 15 ha. Until that point, it had been a wheat field, but the four were successful in converting 10 ha into paddy fields, with an average of 2.5 ha per person. In case No. 1 in 1989, six invited farmers had emigrated from HuaNan County at the recommendation of friends. Among the six households that settled in 1989 as invited farmers, two households returned home the following year in 1990 and another two households went home in 1991. Only two of the six households are still there today. This situation shows that the initial set up for rice farming was very difficult.

Although the second stage of rice farming began in 1993, nearly all areas converted to rice farming in 1994 because of the recovery of rice price and government efforts to improve the land. An additional reason was that PG No. 17 had relatively low-lying topographical features, so it was easier to farm rice from a water resource management point of view. Although X State Farm started rice farming in 1985, they prioritized PG No. 22, which had the lowest-lying topographical features of all the State Farms, and therefore delayed the transition of PG No. 17 for 10 years.

With the transition to rice farming, paddy field restoration work in 1993 was done uniformly across the Production Groups with a labor cost of approximately 15,000 yuan/ha. Though the state farmers had to bear the costs, they were able to get loans from the State Farm through the Production Group. There were two repayment periods: 1 year and 2 years. The repayment was to be made after harvest in cash or in kind. Most of the costs were associated with the groundwater wells and seedling houses that were constructed across the board in 1993–1994 and 1996, respectively. After 1994, construction work on these two types of facilities was carried out individually. Thus, the function of the Production Group was drastically reduced and the loan system for the State Farmers was also abolished.

As preferential treatment for the transition from dry fields to paddy fields, all agricultural taxes and rents for the initial year were waived. Moreover, the heavy machinery for dry field farming was no longer used, and a gradual shift to paddy field machinery was implemented. However, during this period, the finance loans from the State Farm were abolished.

8.3.3 Mobility of Farmers and the Scale Expansion Process

8.3.3.1 Mobility of Farmers and Change of Scale

Retention rates and the scale changes of farmers are described in Table 8.12. The table was created from a series of data on cultivated land areas for each farmer between the years of 1994 and 2006. Notably, the initial 73 households in 1994 dropped to 65 households in 2006, a decrease of eight households. However, from 1994 to 2006, only 52 households remained, 21 households emigrated, and 13 households immigrated. In 1994, the migration rate was 29 %. At that point, in 1994, there were already numerous invited farmers, and the households that were originally laborers accounted for only 55.4 %. It was found that mobilization within these areas was very high. Migration was seen after decreases in rice farming income, especially in 2003, during which rice farming production dropped dramatically throughout the state farms. One characteristic is that, apart from some cases of replacement (immigration), such emigration led to scaled expansion. The following are the changes in the hierarchy of scale.

The management scale remained in a medium range from 5 to 10 ha, but the highest emigration rate (40 %) came from the group that owned less than 5 ha, which illustrates the larger impact of the drop in rice prices on relatively small

Table 8.12 Mobility and scale variation in PG No. 17 (1994–2006) (Unit: No. of Holdings). (Source: Developed from PG No. 17 data)

		Scale composition in 1994								Move-in	Sum total
		<5	5–7.5	7.5–10	10–12.5	12.5–15	15–17.5	17.5<	Sub-total		
Scale composition in 2006	<5	6	1		1				8	1	9
	5–7.5		15						15	4	19
	7.5–10		1	11				1	13	5	18
	10–12.5		1	1	6				8	3	11
	12.5–15		2			2			4		4
	15–17.5			2			1		3		3
	17.5<				1				1		1
	Subtotal	6	20	14	8	2	1	1	52	13	65
Emigration		4	8	6	1	1	1		21		
Total		10	28	20	9	3	2	1	73		

scale farmers. On the other hand, immigration was concentrated in the medium-scale class, with the largest scale not exceeding the 10–12.5 ha range. Out of the 19 large-scale households, 6 households actually increased their scale during this time. Therefore, even though there were fluctuations in the price of rice, certain stocks of rice were available exclusively among the large-scale farmers. Details of the scaled expansion are investigated in the following study of the nine households that saw scale increases.

8.3.3.2 Farmers' Characteristics and the Scaled Expansion Process

Table 8.13 shows the basic characteristics of the scaled expansion process. Looking at the family structure, five households were families of five spanning three generations, and four households were families of three or four spanning two generations. The principal operators were in their thirties or forties. It was characteristic of these households that the principal operators were young. The labor force consisted of 25 persons in total (16 males, 9 females) with 2–3 people per household. By generation, most of them were in their twenties to forties: nine in their twenties, eight in their forties, and four in their thirties. No correlation was observed between the operation scale and the size of the family labor force.

In terms of changes in the area of farmlands of the surveyed households up to this point, all households except for No. 6 had increased their scale of operation. The sampling was performed in accordance with the size distribution in the Production Group based on the operational scale in 2006. As No. 9 and No. 5 expanded their farmland in 2007 and No. 10 (4.1 ha) abandoned farming (not shown on the table), the proportion of small-scale farmers decreased and variations of scale among different hierarchies were reduced[3]. In 2006, all of the five large scale farmers (up to 9 ha) saw scale increases. No. 1 and No. 2 developed their paddy fields during the first period, and moreover, they returned their initial fields in exchange for ones with better conditions to further expand their farming areas. In the case of No. 8, mentioned earlier, this household stuck with their initial paddy field with bad conditions. Household No. 8 was unable to take advantage of the opportunities to increase its farmland size. With the scaled expansion of households No. 9 and No. 5, the scaled ranking by order of settlement year broke down. Also, due to the results of the scaled expansion and retirement from farming by small-scale farmers, all households now have an operational area of 7 ha or more.

Because these farmlands were under state ownership, scaled expansion did not require payment of land prices which was required in ordinary agricultural areas. In some cases, however, compensation was paid for the tenant's right to well use, etc.,

[3] At first the farmers selection was as follows: the largest scale farm (No. 1: 18.3 ha); two large scale farms of more than 10 ha (No. 7: 14.3 ha; No. 2: 12.0 ha); three upper-medium scale farms of 7.5–10 ha (No. 4: 9.9 ha; No. 3: 9.0 ha; No. 6: 8.0 ha); three lower-medium scale farms of 5–7.5 ha (No. 8: 7.2 ha; No. 9: 6.5 ha; No. 5: 5 ha); and one small scale farm of less than 5 ha (No. 10: 4.1 ha).

Table 8.13 Basic information of the targeted households (Family, Land, History). (Sources: Data from farmer investigations in 2006 and 2008)

	No. 1	No. 7	No. 9	No. 2	No. 5	No. 4	No. 3	No. 6	No. 8
Number of farm household	5	3	4	3	3	5	5	5	5
Labor force	2	3	3	3	3	3	3	2	3
Operator	m33,f32	m41,f37	m30,m26	m42,f42	m45,f43	m29,f28	m26,f24	m57,f55	m47,f44
Children (age)	m10	m18		m17	m20	m2	f4	m28,f27	m24,f24
Parents (grandchildren)	m63,f58		m61,f57			m49,f48	m58,f53	(m2)	(m2)
Operation area (ha)	18.3	14.3	13.0	12.0	10.0	9.9	9.0	8.0	7.2
Classification	Invited	Invited	Former machinery team	Former machinery team	Move-in	Invited	Former machinery team	Former machinery team	Invited
Move-in year	1989	1995	1962	1974	2004	1998	1978	1968	1990
Before move-in	Farmer in Huana County	Farmer in Boli County	Shandong Prov. Pingyuan County	Machinery team in H State Farm	Engaged in carrier business at home	Rice farmer in Wuchang County	PG No. 14 in X State Farm	PG No. 13 in X State Farm	Farmer in Bin County

The underline shows labor force

though the amount was small when compared to the level of land rent. On the other hand, additional investments in land improvement are increasing. The well depths, which initially were 17–20 m, are now growing to nearly 30 m deep due to the lowering of the groundwater level. In order to install electric motors, it is necessary to lay power cables, and more than 10,000 yuan has been invested for that purpose (No. 1 and No. 2).

Scaled expansion is possible given the high mobility of farmers. The question remaining is whether the issues of rice cultivation techniques, particularly the issues of mechanization and labor force, have been properly addressed. In the following section, we will clarify how rice farming mechanization is proceeding and how employed laborers are secured to complement machines, while paying attention to the differences in operation scale.

8.4 Conclusions

In this paper, we have given a detailed analysis of the rapid development of paddy fields in various regions on the Sanjiang Plain in recent years, and have clarified that the state farms and ordinary agricultural areas are different both in scale and speed in paddy field development. Though the farmland area in ordinary agricultural areas is similar to that on the state farms, the percentages of farmland used as paddy fields are quite different. The reason for this is that the state farms not only rely on state programs, but also on the land reclamation system (Bureau-Branch Bureau-Farms), making the state farms' paddy field percentage much higher than that in the ordinary agricultural areas.

Second, we reviewed the process of water conservation development. This is a paddy field development process of conversion from flood control and water logging control as the major work in the initial phase of development, to irrigation as the major work. In the initial phase of the Sanjiang Plain's development, dry farmland operations were the focus. To make the land resistant to frequent flooding, efforts were made in embankment construction and water logging control, seeking to stabilize dry farmland operations (in the 1970s, with direct management by state farms). However, considering that the Plain is a wetland area, this was no easy task. There were also a lot of technical difficulties in rice operations directly managed by the state farms.

The system began to change toward one that included farming households as a unit from the mid-1980s, after reforms and a more open policy adopted by the state. During that period, farming households came forward as the principals in rice operations, and could be divided into two types. One type was ordinary rural farmers, who had experience in crop cultivation and were recruited by the state farms as "immigrants" to teach farming skills. The other type was laborers-turned-farmers, who worked in the "machine operators group" and gained some savings during the state farm period. One well and 10 ha of paddy field the proper scale for a single family's farming operations in this stage.

In this way, the state, state farms, and 10 ha-scale farming families each have played a specific role in the process of paddy field development, and rice operations have been established to some extent.

However, the state did not offer any financial support to the additional investment in soil improvement and maintenance and management of water systems. Also, the state farms had experienced operation problems during the privatization process. Heavy burden had fallen on the laborer-turned-farmer households' shoulders in the end. In consideration of rice prices, agricultural taxes were abolished, but higher land rent and water conservation charges were levied against farming households. Whether rice operations on the Sanjiang Plain will last into the future is closely related to the solution to this issue.

References

Park H (2011) Characteristics of agricultural development on the Sanjiang plain: case study of irrigation and drainage development of state farm. J Agric Sci Technol A 1:751–63

Park H, Sakashita A (1999) Regeneration of family operation in Northeast China and rural organizations. Ochanomizu Publishing, Tokyo, pp 1–334

Park H, Sakashita A, Yoshiida K, Da ZhG (2001) Development of state farm paddy fields and rice planting on the Sanjiang plain, China. Rev Agric Econ 57:85–98

Park H, Zhang JN, Da ZhG, Sakashita A (2009a) Development and mechanization of rice production on the Sanjiang plain in China (I). Rev Agric Econ 64:1–12

Park H, Zhang JN, Da ZhG, Sakashita A (2009b) Labor process and farmer household economy of rice production on the Sanjiang plain in China (II). Rev Agric Econ 64:13–23

Sakashita A, Park H (2004) Chinese state farms and rice production zhi gong, reorganized family operations and farmers associations. Tsukuba Press, Tsukuba, pp 177–207

State Farm's Water Conservancy Annals Editorial committee of Heilongjiang Province (2006) Land reclamation water conservation annals of Heilongjiang province 1947–2000

Chapter 9
Developments of Sino-Russo Timber Trade in the Amur River Basin, with Special Reference to the Transition Period During 1995–2005

Masanobu Yamane

Abstract This research focuses on Sino-Russo timber transportation routes, timber trade flows, and related developments during 1995–2005, to identify important factors and trends leading to changes in timber trade policy. Timber trade statistics from individual customs gateways on the Chinese side of the Amur River Basin are analyzed. These statistics outline recent changes in timber trade policies of both countries. Impacts of the latest policy changes on the future of Sino-Russo timber trade flows are discussed. The findings show that the basin was a core area of Sino-Russo timber trade during the study period. Softwood and hardwood logs were the main import items, with more than 90 % of total timber imports, although this share has been dropping gradually. Analysis of timber trade statistics and recent infrastructure developments along certain transportation routes also reveals increasing import volumes at several small to medium-sized gateways, which have seen substantial improvements in trade-related infrastructure. A key trade policy triggering changes in the Sino-Russo timber trade was the Russian log export tax increase in 2007, which increased sawn wood imports from Russia along with a diversification of trade flows.

Keywords China-Russia timber trade • Amur River Basin • Transportation path • Trade flow • Russian log export tax

9.1 Introduction

The Amur is an international river running through Mongolia, China, and Russia. Its length is 4,444 km including tributaries, and its watershed area is 2,051,500 km^2. Forests are a key element of the landscape in the Amur River Basin and are very important in maintaining the watershed's ecosystem and material flows, from the

M. Yamane (✉)
Kanagawa Prefecture Natural Environment Conservation Center, 657 Nanasawa, Atsugi, Kanagawa 243-0121, Japan
e-mail: yamane.5wxw@pref.kanagawa.jp

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_9

river's upper tributaries in China and Mongolia to the Sea of Okhotsk in Russia (Shiraiwa 2005; Onishi et al. 2008; Simonov and Dahmer 2008).

However, since the beginning of the twentieth century, forests in the basin have been either destroyed or seriously degraded. This has mainly been because of agricultural and forestry development but also because of forest fires (Himiyama 2002; Simonov and Dahmer 2008). Forestry activities in China's Heilongjiang Province, which accounted for a large portion of activities on the Chinese side of the basin, progressed until the end of the twentieth century, seriously depleting its forest resources (Dai 2000). Forests on the Russian side of the basin remained relatively untouched until recently, but after the collapse of the Soviet Union in the early 1990s, export-oriented forest development expanded rapidly (Sheingauz et al. 1996; Kakizawa and Yamane 2003). After 2000, China emerged as a major importer of Russian timber, and forest products from the Amur River Basin became a major source of timber supply (Kakizawa and Yamane 2003; Yamane 2003, 2013; Lankin 2004; Sheingauz et al. 2005; Song et al. 2007). However, export-oriented forest development in Russia, mainly driven by demand in China, is likely to bring about further environmental degradation and damage to the entire watershed ecosystem and material flows. Thus, it is important to understand recent developments of the Sino-Russo timber trade and to consider the future of forest exploitation from the viewpoint of nature conservation and wise resource use in the Amur Basin.

Several studies were conducted of the Sino-Russo inland border timber trade in the years immediately after the collapse of the Soviet Union (e.g., Newell and Wilson 1996; Waggener et al. 1996; Yamane and Lu 2001; Sheingauz et al. 2005), and these revealed key gateways of the Russia-to-China timber trade. More detailed studies were conducted with a focus on the flow of timber from Siberia and Russian Far East to China (Yamane and Lu 2001; Yamane 2003; Lankin 2004; Song et al. 2007). These studies determined timber flows from Russia to China using customs statistics from the Sino-Russo border, but they did not take into account how changes in conditions such as the trade policy environment and improvements to customs infrastructure affected both the quantity and nature of timber flows from Russia to China. Most studies focused on major customs gateways, but it became clear that more attention was needed on small and medium-sized gateways, because improvements of customs and related infrastructure have progressed very quickly at both major and minor gateways.

Thus, the purpose of this chapter is to examine Sino-Russo timber transportation routes, timber flows, and related developments during 1995–2005, to identify important factors and trends leading to changes of timber trade policy. The chapter analyzes timber trade statistics from individual customs gateways on the Chinese side of the Amur River Basin, and outlines recent changes in timber trade policies of both countries. Finally, impacts of the latest policy changes on the future of Sino-Russo timber trade flows are discussed.

To gather information on timber flow from Russia to China and timber trade-related policies, the author interviewed experts or related parties in Beijing, China, ten times between 2001 and 2009, and in the city of Khabarovsk in Khabarovsk Krai, Russia, in December 2004 and August 2008. To investigate recent improvements of individual customs facilities in border areas of the basin, the author personally inspected conditions in Chinese gateway cities and towns (Mudanjiang, Jixi, and Jiamusi in Heilongjiang Province) eight times between 2003 and 2008. In addition to these field surveys, the author analyzed the latest conditions of the last three locations using information from internal and external sources, such as relevant websites, literature, and documents.

The figures of timber trade volume at individual customs facilities were acquired from China Customs Statistics from 1996 to 2005. Then, the author compiled annual import volumes by wood species or types according to the Harmonized Commodity Description and Coding System (HS code).

9.2 Transportation Routes and Their Development

9.2.1 Route Variation

Timber is transported from Russia to China by rail, ship, ferry, and truck, but the majority by rail. As shown below, most of this transport passes through inland border corridors. Routes used for transport can be roughly partitioned into the following:

1. From Eastern Siberia or Russian Far East by rail on branch lines of the Trans-Siberian Railway to the border, and then by rail or truck into China
2. From nearby border areas, and then carried across to China by truck or ferry
3. From Eastern Siberia or Russian Far East by rail on the main line of the Trans-Siberian Railway to timber export seaports such as Nakhodka and Vladivostok in Primorsky Krai, and then shipped to seaports in China such as Dalian and Tianjin
4. From Eastern Siberia or Russian Far East by rail along the Baikal-Amur Railway to Russian timber export seaports such as Vanino and Sovgavan. A common variation on this route is the export of logs from Nikolayevsk-na-Amurla at the river mouth. Recently, because transportation on the Amur River has been opened for trade, routes leading to China's river ports have also gradually opened. Among such sea-to-river routes, there is a new one that begins at a seaport, such as De-kastri and Sizuman, and then travels up the Amur River to river ports in China. In this case, logs are sometime re-shipped from Nikolayevsk-na-Amurla or Khabarovsk
5. From Khabarovsk and Primorsky Krai by truck directly to timber export ports such as Olga, and then shipped to major seaports such as Dalian, Qingdao, and others

Among these five routes, the first two are the major ones used to export timber to China from Russia. More than 80 % of timber trade between the two countries in 2004 crossed via inland border points (Fig. 9.1).

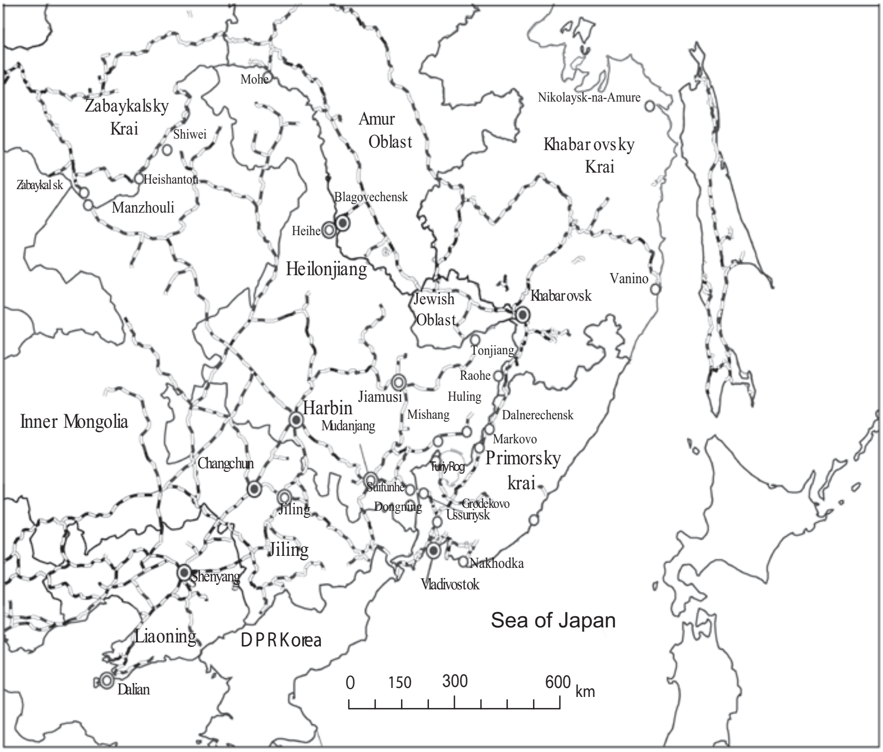


Fig. 9.1 Map of Amur River Basin

9.2.2 Gateways in Main Amur River Watershed

On the main channel of the Amur River, the Manzhouli gateway in the Inner Mongolia Autonomous Region is the only route connected directly by railroad to the Russian locality of Zabaykalsk in Chita Oblast. There are also two small routes used in the province, and eight small or medium-sized gateways in China's Heilongjiang Province, where Russian timber is transported by truck or ferry from Amur Oblast, Jewish Autonomous Oblast, and Khabarovsk Krai (Table 9.1).

Among the above locations, Manzhouli is the major gateway. In 1992, this once-small border city was one of the first inland border cities opened up by the People's Republic of China. After 2000, the city developed dramatically, with construction of a new domestic airport connecting to Beijing and Harbin, as well as highways leading to Harbin, the capital of Heilongjiang Province, through Hailar. Manzhouli established a processing zone for import materials in 2003, and the project has progressed steadily since. A wood-processing area was established in the zone in 2004, and now more than 40 Russian wood-processing enterprises are in operation there. As log imports from Russia increased, freight yards were enlarged in 2004 to expand capacity, and construction of a new yard is planned.

Table 9.1 China's border gateways to Russia in the Amur River Basin

Watershed	Large gateway	Small/medium-sized gateway
Main Amur	RW, RD: Manzhouli in INM	WT: Heishantou, Shiwei in INM
		WT: Moho, Heihe, Sunwu, Xunke
		Jiayin, Luobei (Fujin), Tongjiang
		Fuyuan in HJN
Ussuri	RW, RD: Suifunhe in HJN	WT: Raohe in HJN
		RD: Mishan and Dongning in HJN
		RD: Hulin in HJN

INM inner Mongolia autonomous region, *HJN* Heilongjiang province, *RW* railway connection, *RD* road connection, *WT* water connection

The Heihe gateway in China, which connects to Blagoveshchensk, the capital of Amur Oblast in Russia, was established as a free trade zone on the border, and includes relatively new construction projects such as a cross-border river bridge and highways leading to Harbin. The Tongjiang gateway, which connects to Leninskoe in the Jewish Oblast, also had its river port upgraded to increase capacity after 2004. Timber imported at the river port is transported in log booms from the lower reaches of the Amur, and is made up mostly of coniferous tree species such as larch and spruce. Improvement of the port facility has been driven by the largest Chinese importer of timber from the Russian Far East, which based itself in Suifunhe after the resolution of border issues. The city also has highway construction projects leading to Harbin through Jiamusi. Other small gateways on China's side, such as Mohe and Fuyuan, have also been expanding their gateway capacity.

9.2.3 Gateways in the Ussuri Watershed of the Amur River Basin

In the Ussuri watershed of the Amur Basin, the Suifunhe gateway in Heilongjiang Province is the only corridor connected directly by rail to Russia's Grodekovo station (in Pogranichnyy) in Primorsky Krai. Distances to Ussuriysk and Vladivostok are 123 and 230 km, respectively. Like Manzhouli and Heihe, Suifunhe was opened up as one of the first border cities in 1992, and is a core gateway of the Sino-Russo timber trade, especially for timber from the southern part of the Russian Far East.

The Suifunhe railroad gateway has 24-h operation with an annual handling capacity of more than 6 million m^3, having expanded in stages since 2000. Improvement of its cargo terminal station (Suifunhe North Station) has been completed. The gateway has a road connection with Russia, constructed in 1990, and it joins a highway leading to the Chinese city of Harbin through Mudanjiang. An approved highway project will connect to Manzhouli.

Other small routes include the Bikin-Raohe (or Jao-ho) river corridor (Khabarovsk Krai to Heilongjiang Province), Markovo-Hulin river bridge corridor (Primorsky Krai to Heilongjiang Province), Turiy Rog-Mishan land corridor (Primorsky Krai to Heilongjiang Province), and Poltavka-Dongning road corridor (Primorsky Krai to Heilongjiang Province). Trucks can cross the border along the Bikin-Raohe river corridor during winter when the rivers freeze, and along the Markovo-Hulin corridor by border bridge. Among the small gateways on the Chinese side, Dongning, which lies near Suifunhe around 154 km from Ussuriysk in Primorsky Krai, has grown rapidly after 2005. The first stage of construction along the corridor of the Dongning-Poltavka border trade zone was completed in 2005, after which the town began trial operations of its Sino-Russo international trade market. The small border town of Dongning has already seen branch highways constructed to connect it with the Suifunhe-Harbin route. Additionally, previously suspended rail operations on the railroad connecting to the Mudanjiang-Suifunhe line were resumed and extended to the border, and the Dongning railroad station was established. The plan is to connect this railroad to the railway on the Russian side that leads to Ussuriysk, a project that has been approved by the Russian central government. Once this project is completed, this improved corridor will have a transport capacity as large as the Suifunhe-Grodekovo corridor. In addition to these upgrades, the Raohe customs facility was completely renovated to expand its handling capacity. There are also several other planned projects, such as the construction of a bridge crossing the river, a free trade zone, and development of a highway leading to Harbin through Fujin.

In contrast to these improvements on the Chinese side, gateway improvements on the Russian side continue to lag, with no significant progress since the Soviet era, although railroad construction connecting to Dongning and improvement of loading capacity at the Grodekovo station were carried out in 2008.

9.3 Timber Flows from the Amur River Basin Through Land Border Gateways

9.3.1 General Trends

The volume of timber flowing from the Amur Basin in Russia to China increased significantly from 1996 to 2005, growing from 476,000 to 15,872,000 m^3, in tandem with the trend of China's total timber imports (Table 9.2). The share of the basin timber trade against total imports was around 80 %, indicating that the basin is at the core of Sino-Russo timber trade. Softwood and hardwood logs are the main imports, at more than 90 %, but this share has been gradually declining.

Comparing the Ussuri and Amur watersheds, the volume of timber flow from the Ussuri was more than 60 % in 1996 relative to the basin total, and it was larger than that from the main Amur River Basin. In 1997, however, flow from the latter basin reached a 50 % share and then increased to around 60 %. As for the types of log exports from Russia to China, there are major flows from both watersheds, but the flow of sawn wood from the main Amur watershed has increased gradually since 2002. The share of sawn wood imports from that watershed was 50–70 %, indicating that the Zabaykalsk–Manzhouli corridor has been the major route for the Russian sawn wood trade. This is because most imported sawn wood is processed at enterprises in remote areas such as Irkutsk in eastern Siberia and Krasnoyarsk in western Siberia, and then transported to China by rail.

Table 9.2 Timber import volume from Russia to China with focus on the Amur River Basin (Unit: 1000s of cubic meters, m^3). (Source: Compiled from Chinese customs trade statistics by the author)

Watershed	Main Amur				Ussuri				Amur Basin		China's total imports from Russia	
Gateway	Manzhouli		Others		Suifunhe		Others					
Year	LG	SW	LG	SW	LG	SW	LG	SW	LG	SW	LG	SW
1996	147	3	19	1	272	4	30	0	468	8	529	11
1997	382	6	14	0	381	4	14	0	791	10	949	11
1998	665	7	16	1	561	2	8	1	1,250	11	1,591	12
1999	1,784	41	135	8	1,341	14	18	4	3,279	66	4,305	82
2000	2,070	82	144	7	2,038	32	10	3	4,261	125	5,931	158
2001	2,932	182	457	1	3,144	–	4	–	6,537	–	8,766	308
2002	5,264	383	624	15	4,678	90	6	31	10,572	520	14,806	552
2003	5,241	397	563	14	4,954	103	6	19	10,765	533	14,368	561
2004	6,975	612	769	7	5,245	124	9	25	12,997	767	16,962	799
2005	8,095	720	783	14	6,097	132	5	28	14,979	893	20,045	1,057

LG logs, *SW* sawn wood products

Table 9.3 Russian timber flows at China's two major gateways in 1997 and 2002. (Source: Chinese customs trade statistics compiled by the author)

		Logs		Sawn woods	
		1997	2002	1997	2002
Suifunhe	Softwood	3.3	3909.6	0.4	36.6
	Hardwood	378.0	768.6	3.3	52.7
	(Oak)	5.3	146.6	0.2	26.0
Manzhouli	Softwood	381.6	5185.0	5.8	330.1
	Hardwood	0.0	79.0	0.1	53.3
	(Oak)	0.0	0.0	0.0	0.0

9.3.2 Large Gateways

Timber flows through the major gateways of Manzhouli and Suifunhe have grown sharply over the last 10 years, but the types of wood have varied based on timber origin. Based on interviews at the Manzhouli gateway, most imported logs were from eastern Siberia, partly near border regions such as Chita Oblast and Amur Oblast. As for Suifunhe, most logs are transported from the Russian Far East, but softwood logs such as red pine and larch originate in eastern Siberia.

As for species or types of imported timber, the Manzhouli gateway sees mostly softwood, but the import of broadleaf logs such as birch increased after 2002 (Table 9.3). After establishment of an ambitious processing complex in the city, around one-third of imported logs are roughly processed and then transported to secondary markets for further processing. Very recently, some Chinese-made products made of processed Russian wood have been transported back through Russia for export to Europe.

Many hardwoods are imported from Russia through Suifunhe, the major gateway in the Ussuri watershed. In the mid 1990s, before China's Natural Forest Protection Project (NFPP) was instituted, most imported timber was hardwood logs. Even until recently, hardwood flow accounted for about 30% (more than 50% monetarily) of total imports, despite softwood imports having grown sharply. Of the total hardwood border trade from Russia to China, around 70% is transported through this corridor, revealing that Suifunhe is the key gateway for the hardwood trade, where there are substantial imports of hardwoods such as ash and oak from the southern part of the Russian Far East. According to trade statistics from the first half of 2004, the share of total imports of hardwoods (such as ash, oak, linden, and elm) was greater than 20% by volume and 40% by value.

In Suifunhe, Russian timber-processing industries have been developing since around 2000, and about 30–50% of imported logs are now processed there. In early stages, most enterprises processed semi-finished products, but the production of value-added products such as laminated lumber has been increasing over the last 3–5 years. Consequently, there are numerous processing factories in a limited city area, so a shortage of available sites for new factories has emerged as a limit on further development. Thus, Suifunhe's city government stepped up efforts to expand its industrial base, and ultimately decided to relocate small primary processing factories to a neighboring town in an effort to accommodate more factories.

9.3.3 Small and Medium-Sized Gateways

The recent share of timber flow of both logs and sawn wood passing through small and medium-sized gateways in the Amur River Basin is around 5%. Therefore, these gateways are still a very small part of the overall Sino-Russo timber flow. Gateways at which flows exceed 100,000 m^3 are Tongjiang, Luobei and Fujin, all in the main Amur watershed. Among these, the import volume transported through the Tongjiang gateway has increased annually, reaching around 500,000 m^3 in 2005. At the Mohe gateway in the headwaters of the Amur River, imports were around 100,000 m^3 after 2001, despite the fact that the customs office is only open in winter when the river freezes. This is partly owing to the convenience of transportation, because the distance between Mohe and Dzhalinda on the Russian side of the gateway is only 1.5 km, and a branch of the Trans-Siberian railroad reaches Dzhalinda.

The level of imports at Heihe, one of the first Chinese border cities to open up, together with Manzhouli and Suifunhe, decreased after 1999 and annual imports have been steady around 30,000 m^3 in the last few years. Import volume at Fuyuan, which connects to the city of Khabarovsk in Khabarovsk Krai, has remained around 20,000–60,000 m^3 annually since 2000. Annual flows at other gateways have been around 10,000 m^3 with some fluctuation, whereas timber imports passing through Xunke, Raohe, and Mishan are minimal. Gateways where timber flows exceed 10,000 m^3 include Luobei in the main Amur watershed, and Hulin and Dongning in the Ussuri watershed. Among these, the flow at Dongning has been growing

Table 9.4 Share of timber flow through gateways in Ussuri watershed by type of wood, compared with total through all small and medium-size gateways in the Amur Basin (Unit: %). (Source: Chinese customs trade statistics compiled by the author)

Year	Logs		Sawn woods	
	Softwood	Hardwood	Softwood	Hardwood
1996	0.00	60.86	9.3	17.3
1997	0.00	51.06	0.0	7.7
1998	6.09	26.78	59.4	1.3
1999	7.56	4.48	27.9	6.0
2000	0.80	5.41	11.3	18.9
2001	0.41	0.46	–	–
2002	0.32	0.63	15.7	51.8
2003	0.23	0.82	20.5	37.3
2004	0.02	1.15	40.6	36.9
2005	0.04	0.56	41.6	25.6

steadily since 2000. Annual import volume through Heihe was more than 10,000 m^3 in 2000, but it has recently dropped sharply to near zero.

Examining timber flows by tree species, most were softwood logs moved through gateways in the main Amur watershed, except in 1998 when the NFPP was launched in China. By contrast, mostly hardwood logs were transported through the gateways in the Ussuri watershed before 1997, but the share dropped drastically after that (Table 9.4). After 1998, the volume of sawn wood was high compared with that of logs. To determine the reason for differences in timber flows at the small and medium-sized gateways, it is necessary to carefully examine other factors. These include the state of development of wood-processing facilities near each gateway, geographic relationship with nearby major corridors, handling capacity of customs points, transportation infrastructure, and locations of Russian timber product suppliers.

9.4 Recent Changes in Key Timber Trade Policies of Russia and China

9.4.1 Russia Boosts Log Export Tax

In February 2007, Russia's central government announced a graduated but sharp rise in log export taxes to take effect after July 2007, and then executed the first step as planned in 2009 (Table 9.5). This system of export taxes on Russian timber has been in operation since then. The previous export tax on soft logs was 6.5 % or € 4/m^3 (around US $ 5.2). In July 2007 it was increased to 20 % or € 10/m^3. Finally, after January 2009, the tax was set to increase to 80 %, or € 50/m^3. The export tax rate on hardwood logs (such as oak, beech, and ash) and even semi-finished products is also set to rise sharply. This drastic and far-reaching policy change is

Table 9.5 Russian export tariff on logs after 2007

Item	Rate / Minimum amount	Jul 1, 2007	Apr 1, 2008	Jan 1, 2009
Softwood logs	%	20	25	80[a]
	€/m^3	10	15	50[a]
Hardwood logs	%	24	24	50
	€/m^3	10	10	80[b]
Poplar	%	5	5	50
	€/m^3	10	15	50
Semi-finished products with bark thickness of 15 cm or less	€/m^3	20	25	80

[a]On December 2008, the Russian government announced that implementation would be postponed until January 2009
[b]The tax was raised to € 100/m^3 after February 2008

in essence a log export ban, and it significantly reduced log exports from Russia to China in 2008. Being the top importer of logs from Russia, China has suffered a serious impact of this action, and the prevailing view of China's wood industry is that their efforts to shift their supply of raw wood materials away from domestic supplies to Russia's timber supply will incur a setback.

9.4.2 Adjustment of China's Trade Taxation Policies in Preference of Russian Timber

Gradual moves by China in recent years to deregulate or reduce trade taxation on Russian timber products, which fueled a steady increase in timber trade between Russia and China, were announced sequentially so as to control the trade of processed timber. This type of adjustment was eventually made to cover value-added wood products. One key adjustment was a gradual reduction of the value-added tax refund rate. Since China's central government announced major adjustments to this rate for export products in January 2004, significant adjustments were implemented, including cutting or elimination of the tax refund rates. The announcement of July 2007 listed 2831 items for control, and value-added wood products such as plywood also had refund rate cuts. Additionally, non-renewable wood products, such as disposable wooden chopsticks, were listed as prohibited and restricted items for the processing trade.

Changes linked to the announcement have been expanding the list of controlled processed-timber items for value-added trade since autumn 2006. In a new list issued in August 2007, many wood products such as wood furniture, wood panels, and plywood were included as controlled products. Wood-processing trade enterprises handling these items are now required to submit a deposit amount in currency equivalent to the customs duty and value-added tax. No permits are being issued for new foreign capital enterprises, and existing enterprises are required to increase their guarantee deposits for value-added products in processing trade. However, processing trade enterprises in Chinese inland regions are exempt from the deposit requirement and given favorable treatment. Thus, Russian wood-processing trade enterprises, many of which are in coastal regions and manufacture products on the controlled products list, will face difficulties in generating enough profit to continue doing business, and are consequently likely to switch to more value-added wood production or relocate to interior regions.

9.5 Discussion

9.5.1 Background of China's Rapid Increase in Timber Imports from Russia

Analysis of China's trade flows over the decade 1995–2005 reveals that among various forest products, log imports have increased the fastest in both proportion and volume. For example, from 1996 to 2005, the country's total log imports grew from 3,186,000 to 26,309,000 m^3, a factor greater than seven. Annual incremental growth in volume roughly corresponds to the reduction in China's domestic timber supply, which is linked to implementation of the NFPP (Yamane 2003). Over the same period, Russian timber as a share of China's total timber imports rose dramatically from 17 % in 1996 to 68 % in 2005, suggesting that logs from Russia have been making up for China's supply and demand gap.

9.5.2 Infrastructure Improvement as a Driving Force of Change

Sino-Russo inland border trade in the Amur River Basin is likely to become more active because of structural changes over the next 10 years. Timber flows through the two key gateways, Manzhouli and Suifunhe, are expected to grow even more, because their handling capacity is being rapidly increased and there has been a buildup of Russian wood-processing enterprises during 2002–2008 (Khabarovsk Krai 2008).

One challenge ahead is growing competition for transportation infrastructure with other import raw materials, such as oil and metals. To such avoid problems, there is a possibility that the import of semi-processed Russian wood products—some produced by Chinese wood-processing enterprises in Russia—could increase sharply, owing in part to Russia's log export tax increase. Therefore, highway transport of timber in China will become more prevalent.

There is also the possibility that previous upgrades of small and medium-sized gateways will diversify timber flows from Russia to China, but any change strongly depends on Russia's progress toward upgrading its gateways. Because semi-finished wood products are lower in volume and lighter in weight compared with logs, these import flows will become more flexible and diversified, depending on the location of enterprises that manufacture the final products. It is said that logging sites on the Russian side of the Amur Basin have become more remote, especially along the routes of major timber transport infrastructure such as railways or major roads (Kakizawa and Yamane 2003). Thus, there is potential for any unexplored forests with more difficult access along the border to be developed and the semi-finished wood-processing industry to become established in such locations. These changes would enhance timber trade at small and medium-sized gateways. The recent foreign investment promotional programs of Russian local governments for the wood-processing industry near the border (Khabarovsk Krai 2008) could contribute to further changes, as could border-side construction of free trade zones for that industry.

9.5.3 Impacts of Timber Trade Policy Changes and Shifting Economic Conditions

To some extent, China's recent changes to its trade policy may prompt establishment of enterprises that manufacture finished wood products close to several border gateways, triggering changes in the structure of the wood-processing industry. Furthermore, because of Russia's new export tariff on logs, the previous pattern of timber trade will likely be significantly altered compared with the days when Russian logs were imported across the inland border, transported to coastal industrial areas in China for value-added processing and manufacturing, and then exported to foreign countries.

The most recent key timber trade policy leading to change in Sino-Russo trade was Russia's log export tax increase in 2007, as mentioned earlier. It appears that this measure brought about impacts such as a rise in Russian log prices, a spike in China's log imports from Russia in 2007, and a decrease of log imports to China and expansion of imports of Russian sawn wood in 2008 (Tai 2008). The Russian government, however, abruptly decided to postpone a further increase of its export tax on coniferous logs, but the log export tax on hardwood was increased further as planned. This new situation will bring about a recovery of Russian coniferous log imports and a sharp increase in sawn wood imports to China, and hardwood log imports from Russia will decrease significantly. In fact, after the announcement of Russia's decision, the major gateways for importing Russian coniferous logs such as Manzhouli and Erlenhot began to recover their coniferous log import volume, albeit not to former levels. Thus, continued careful monitoring is essential to analyze future trends.

Additionally, recent deteriorating economic conditions, evident especially by a decrease in demand for wood products in countries that consume Russian timber, will also impact the Sino-Russo timber trade. The global financial crisis at the end of 2008 led to a much greater decrease in demand for wood, and the timber trade from Russia to China as well as China's own timber industry began to exhibit entirely different characteristics.

9.6 Conclusion

In this chapter, Sino-Russo timber trade during 1995–2005 was analyzed. From the viewpoint of sustainability for forest development in the Amur Basin, the following conclusions were reached. First, the basin has become the most active area of timber trade from the Russian Far East and eastern Siberia to China, owing to rapid increase of China timber importing since the mid 1990s. Second, previous development of border trade infrastructure and the diversification of transportation routes, especially through land gateways between Russia and China, have encouraged expansion of Sino-Russo timber trade and have consequently triggered further exploitation of forest resources in the Amur Basin for export to China. Finally, past changes of forest resources and trade-related policies in both countries, such as Russia's log export tax increase in 2007 and China's NFPP in 1999, have greatly affected trends in the timber trade from Russia to China and the development and diversification of transportation routes.

The state of Sino-Russo timber trade has been very dynamic. Underlying causes of recent changes in this trade have been closely linked to economic, policy, and infrastructure changes. Continued monitoring and further studies are needed to examine the dynamics of these key factors in greater depth.

Acknowledgement This research owes much to the thoughtful and helpful support of Professor Lu Wenming, Division of International Cooperation, Chinese Academy of Forestry, and Professor Hiroaki Kakizawa, Graduate School of Agriculture, Hokkaido University. The author would also like to thank the late Professor Alexander Sheingauz and Dr. Natalia Antonova, Economic Research Institute, Russian Academy of Science, and Ms. Hu Xīnzhī, Division of Wood Industry, Chinese Academy of Forestry, for their help in collecting and clarifying information. This study was supported in part by the Amur-Ohkotsk Project of the Research Institute for Humanity and Nature and the "China Wood Market" research project of the Forestry and Forest Products Research Institute, Japan.

References

Dai Y (2000) National Forest Management and Community in China, its development and process. Japan Forestry Investigation Committee, Tokyo (in Japanese)

Himiyama Y (2002) Long-term land use/cover change in Northeast China. Study process impact land-use change China final report LU/GEC second phase (1998–2000). National Institute of Environment Studies (NIES), Tsukuba

Kakizawa H, Yamane M (eds) (2003) Russian forest and forestry. Japan Forestry Investigation Committee, Tokyo (in Japanese)

Khabarovsk Krai (2008) Timber industry of Khabarovsk territory in 2008. Khabarovsk Krai, Khabarovsk

Lankin A (2004) Status and trends in forest product exports from the Russian Far East and Eastern Siberia to China. Forest Trends, Washington, DC

Newell J, Wilson E (1996) The Russian Far East: forests, biodiversity hotspots and industrial developments. Friends of the Earth Japan, Tokyo

Onishi T, Shibata H, Yoh M, Nagao S (2008) Mechanism for the production of dissolved iron in the Amur River Basin, a modeling study of the Naoli river of the Sanjiang plain. In: Taniguchi M, Fukushima Y, Burnett WC, Haigh M, Umezawa Y (eds) From headwaters to the ocean: hydrological changes and watershed management—proceedings of the international conference on hydrological changes and management from headwaters to the ocean, HYDROCH 2009, pp 355–360

Sheingauz AS, Karakin VP, Tyukalov VA (1996) Forest sector of the Russian Far East, a status report. Economic Research Institute, Khabarovsk

Sheingauz AS, Lebedev AV, Antonova NY (2005) Russian Far East, China softwood-log commodity chain and livelihood analysis, from the Russian Far East to China. Forest Trends, Washington, DC

Shiraiwa T (2005) Proceedings of the Amur–Okhotsk project. 2:2–30

Simonov EA, Dahmer TD (eds) (2008) Amur–Heilong River Basin reader. Ecosystems Ltd, Hong Kong

Song W, Cheng B, Zhang S, Meng X (2007) Russian logs in China, the softwood commodity chain & Chinese economic development. Forest Trends, Washington, DC

Tai Y (2008) China's timber trade in the upper half of 2008, Shanghai Timber Network. http://www.shtimber.com/Integrated. Accessed 24 Feb 2009 (in Chinese)

Waggener TR, Backman CA, Gataulina E (1996) Outlook for Russian forest product trade with the People's Republic of China. CINTRAFOR working paper, University of Washington, College of Forest Resources, Seattle

Yamane M (2001) China's recent forest-related policies, overview and background from the perspective of economic growth and forest conservation. In: Inoue M et al. (eds) Policy trend report 2001. IGES Forest Conservation Project, Hayama, pp 1–12

Yamane M (2003) Study on changing recent China's timber trade, focusing Sino-Russia logs trade. J Forest Econ 55(12):2–16 (in Japanese)

Yamane M (2013) Russian timber trade trends and the East Asian timber market. J For Econ 65(10):21–30 (in Japanese)

Yamane M, Lu W (2001) Analytical overview of recent Russia-China timber trade. Int Rev Environ Strateg 2:335–347

Chapter 10
Development Process of Timber Harvesting in the Khabarovsk Region, Russian Federation

Hiroaki Kakizawa

Abstract This research focuses on the development process of timber harvesting in the Khabarovsk region of Russia after World War II. The initial stage lasted until the mid 1960s, during which time most tree felling took place in the Komsomol and Lower Ussuri forest districts. Railroad and floating were the main means of transporting timber. Active timber harvesting was undertaken from the mid 1960s until the collapse of the Soviet Union. In this period, all forestry areas in the Khabarovsk region increased their output because of Soviet economic policies, which emphasized development of the Siberian economy. A transition period followed the Soviet collapse in which output sharply declined. However, the 1998 Russian financial crisis prompted an increase in timber production for export. There was intensive felling in the Amgun, Sovgaban, Komsomol, and Lower Amur forest districts, which were geographically advantageous for exporting timber to Japan. Deforestation, which occurred in forests that had good transport, high-quality wood, and easy access to markets, caused resource deterioration.

Keywords Russian Federation • Khabarovsk region • Timber harvesting • Forest history • Intensity of timber harvest

10.1 Background

Various human activities within the Amur River Basin have affected its natural resources, resulting in resource degradation and land-use change. In the Russian part of the basin, that change has not been a significant issue in recent years. Large areas of the basin are still covered by forests; nevertheless, forest resource degradation is a serious problem for both environmental conservation and sustainable supply of timber.

Many researchers have described the degradation of forest resources in the Russian Federation (Shividenko and Nilsson 1996; Kakizawa 2003a). Because these

H. Kakizawa (✉)
Research Faculty of Agriculture, Hokkaido University, 060-8589 Sapporo, Japan
e-mail: kaki@for.agr.hokudai.ac.jp

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_10

studies were based mainly on statistical analysis of the entire Russian trend, the concrete trend of forest development and its consequences at the local level remained unclear. To reconsider sustainable forest management in the Russian Amur Basin, forest development and its effect on resources at the local level should be analyzed.

In this chapter, the forest development process in the Khabarovsk region is examined. This region is the most active for forest development in the Russian Amur Basin. First, the socioeconomic background of forest development is described, and then this development is analyzed by forest district. The relationship between the development and forest resource degradation is also investigated. In the Khabarovsk region, forest fires have been identified as a major cause of forest degradation, together with forest development (Efremov 1989). As such, it is difficult to quantitatively analyze the effect of forest development on forest resources as distinct from forest fires. Therefore, the analysis is qualitative and based on existing case studies.

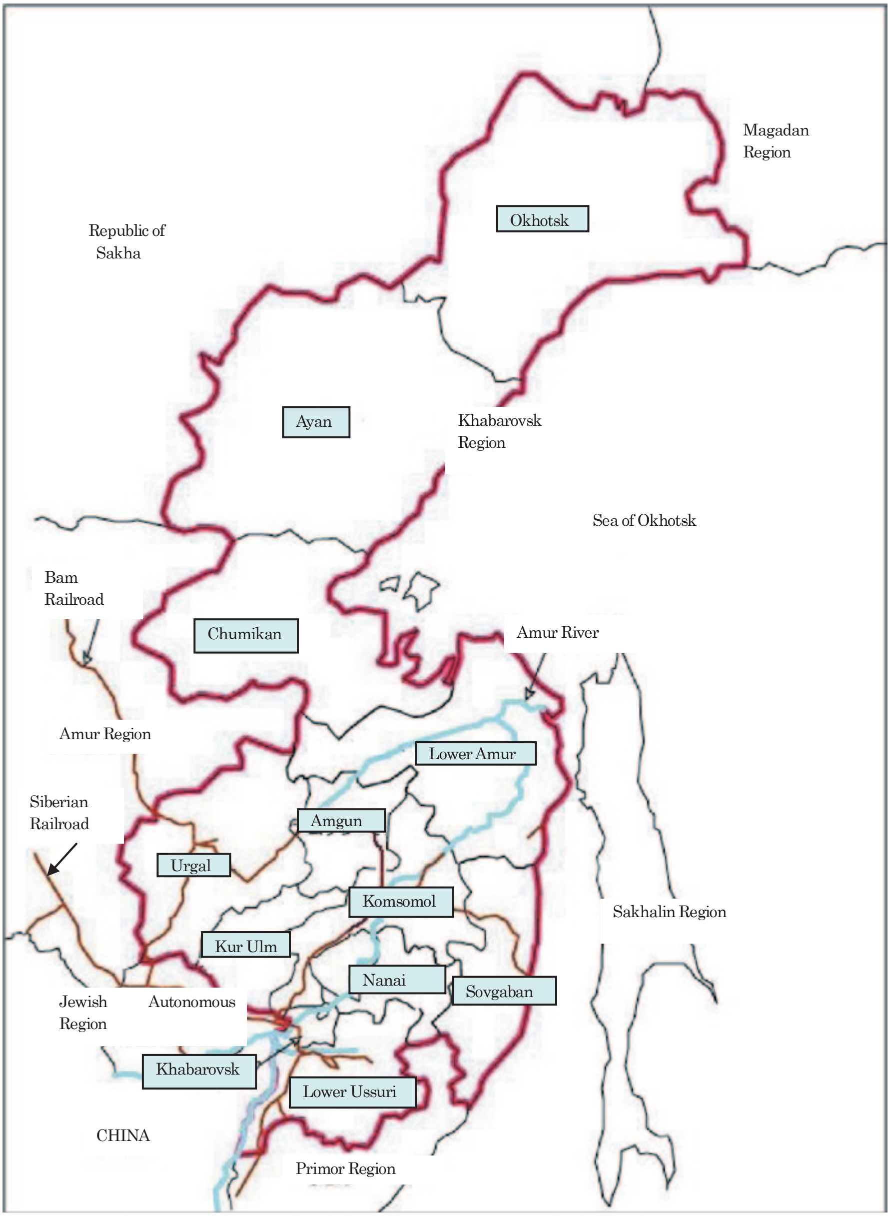
Statistical data on forest development and related activities were collected at the Khabarovsk Regional Forest Department office and Economic Research Institute of the Far Eastern Branch of the Russian Academy of Sciences. Open-ended interviews were conducted with foresters at the Khabarovsk Regional Office and District Forest Offices in the Komsomol, Lower Ussuri, and Nanai forest districts.

The geographic unit for analysis will be the forest district (Лесохозяйственны Район, hereafter FD). The forest management unit for the Russian forest administration is the district forest office (*leskhoze*). However, division, abolishment, and merger of district forest offices was frequent; therefore, it is impossible to follow long-term trends based on the *leskhozes*. However, FD boundaries have not changed since World War II and are therefore suitable for historical analysis. Ayan, Okhotsk, Chumikan, and Khabarovsk FDs were excluded from the study because their timber production was minor. Locations of FDs are shown in Fig. 10.1.

Forest development activities of each FD are evaluated by both volume and intensity of harvest (volume of harvest per hectare), because the total volume of forest resources differs greatly by FD.

10.2 Trend of Forest Development in the Khabarovsk Region

Figure 10.2 shows the trend of logging activities in the Khabarovsk region since 1948. The former USSR government stressed the development of forest resources in the Russian Far Eastern economic region since the late 1960s, which rapidly increased timber production there. Khabarovsk, which was the major timber production region in the Russian Far East, also increased its timber production. Timber production in this region remained strong during the 1970s and 1980s, at around 140–150 million m^3. However, because of economic turmoil after the collapse of the former USSR and its planned economy, the timber harvest dropped drastically in the mid 1990s to a level nearly a quarter that in the 1980s. Although timber began an export-led increase after 1998 because of a decline in the value of the ruble, the timber harvest level remains well below that of the 1980s.



Legend: Forest districts are in the box

Fig. 10.1 Forest districts in the Khabarovsk region

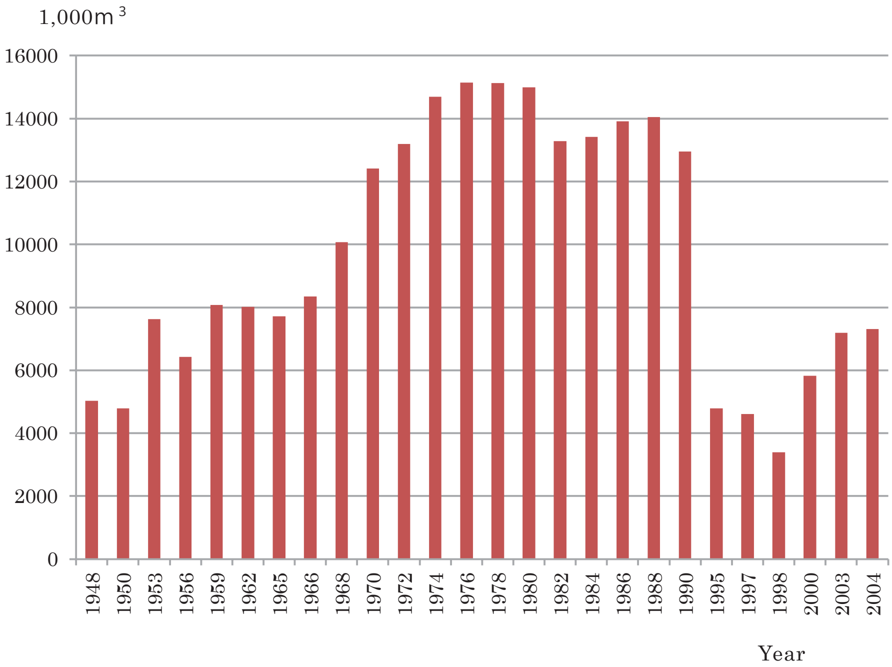


Fig. 10.2 Trend of timber harvest in the Khabarovsk region

Here, forest development in the Khabarovsk region is partitioned into three periods: Period I: 1950–mid 1960s, when timber production began to increase; Period II: mid 1960s–1980s, when production remained high; and Period III: after the 1990s, when production dropped and then recovered because of exports.

Forest development in Periods I and II was carried out under the planned economy of the former USSR, and Period III was during transition from the planned to capitalist economy.

10.3 Forest Development in Period I: The Initial Phase

10.3.1 Policy and Economic Background of Forest Development

The organizational foundation for forest management and development was formed in this period. In 1947, the Ministry of Forestry of the USSR and Ministry of Forestry of the Russian Republic were established. They were the first independent forest administrations in the history of the USSR (Federal Forest Service of Russia

1998). In the same year, the Khabarovsk Regional Forest Office was established under the aforementioned Ministry of Forestry (Danilin 2000a). The Ministry of the Forest Industry of the USSR was organized in 1947 and a national enterprise carried out timber harvesting and processing under control of the ministry.

Forest development in the former USSR was initially active in the European area, where population density was high and industry was developed. Following World War II, the former USSR began to build timber-processing facilities and increase timber harvesting in Eastern Siberia to help counteract effects of the war, although the Russian Far East area was not included in this policy. After World War II, reconstruction of the European part of the USSR was a priority and investment in the Russian Far East was neglected (Bradshaw 1991). However, the importance of a shift in forest development to Siberia and the Russian Far East was recognized in the 1950s, because these areas were rich in forest resources (Federal Forest Service of Russia 1998) and could help balance the distribution of such resources and the timber harvest. Under this policy framework, the volume of timber production began to rise in the 1950s. The Sixth Five-Year Plan (1956–1960) clearly stated that Siberia and the Russian Far East were priority areas for timber development. This direction was continued in subsequent 5-Year Plans (Schiffer 1989).

In 1959, the economic administrative organization was reformed to achieve integrated economic development (Nove 1992), and the forest management organization and state forest industry enterprises were merged to integrate development of the forest sector. However, this reform failed and the timber harvest level stagnated along with other forms of industrial output. Under this integrated system of forest management, the forest management units could not control the harvesting and processing units, and the level of forest management deteriorated (Danilin 2000b).

10.3.2 Trend of Timber Harvest at FD Level

Table 10.1 shows the volume of harvest and Table 10.2 the intensity of harvest by FD. Intensity was highest in the Lower Ussuri FD throughout Period I, followed by the Komsomol and Nanai FDs, and then the Amgun, Kur/Ulm and Sovgaban FDs. The order for total volume of harvest by FD fluctuated during this period; Lower Ussuri was the highest, followed by Komsomol. It is concluded that the Lower Ussuri FD was the most active in terms of timber harvest during this period, followed by the Komsomol FD.

One reason for the high timber production in these two FDs was that they were adjacent to areas that used a large amount of wood. Khabarovsk city and the area along the Ussuri River were settled first and developed as a political center for the Khabarovsk region. Komsomolsk-na-Amur city (Komsomolsk city hereafter) began to develop in the 1930s and became a major industrial town during this period. These two areas consumed a large amount of wood and timber production was carried out to satisfy these demands.

Another reason for their high timber production was advantages in timber transportation. Timber transport in the Khabarovsk region during Period I was

Table 10.1 Trend of harvest volume by forest district in the Khabarovsk region (unit: 1000 m^3). (Source: Khabarovsk Regional Government, Khabarovsk Regional Forest Office)

Forest district	1948	1950	1953	1956	1959	1962	1965	1966	1968	1970	1972	1974	1976
Amgun	0.0	0.0	0.0	268.4	1109.9	763.9	421.5	571.2	686.5	812.0	868.8	958.6	985.3
Komsomol	1038.8	638.7	961.4	897.4	1283.4	1383.0	1126.9	1299.1	1363.4	1241.8	1558.3	1555.8	2053.5
Kur/ulm	112.2	207.8	324.6	219.8	372.3	493.0	504.7	548.2	596.7	726.0	791.3	879.9	976.2
Nanai	235.5	295.0	491.0	546.3	853.6	784.3	781.5	1137.2	992.0	1178.9	1012.4	1289.8	1145.8
Lower Amur	804.9	1012.0	1831.0	780.3	835.7	950.7	1160.3	1268.3	1314.0	1442.0	1626.1	2063.9	2118.3
Lower Ussurii	1083.3	1794.5	1667.7	2131.3	2077.9	2147.7	2163.8	2405.6	2176.6	2184.4	2088.6	2026.8	1950.3
Sovgaban	331.4	372.1	622.0	395.2	437.7	550.0	762.5	719.3	986.7	1055.5	1016.8	935.0	941.6
Urgal	422.0	163.8	327.5	191.4	243.4	283.6	116.5	261.4	1808.6	3659.8	4105.2	4868.6	4874.9
Total	*4028.1*	*4483.9*	*6225.2*	*5430.1*	*7213.9*	*7356.2*	*7037.7*	*8210.3*	*9924.5*	*12300.4*	*13067.5*	*14578.4*	*15045.9*
Forest district	1978	1980	1982	1984	1986	1988	1990	1995	1997	1998	2000	2003	2004
Amgun	921.3	1005.6	852.8	882.4	1001.3	1229.5	837.4	564.0	676.9	474.6	837.9	955.8	1097.7
Komsomol	2281.6	1995.2	1639.6	1502.7	1602.3	1374.5	1590.8	742.0	629.6	514.1	1127.0	1219.4	1149.5
Kur/ulm	903.8	856.2	776.6	801.0	908.2	872.1	450.2	204.0	147.1	84.1	70.9	258.1	339.6
Nanai	902.7	1043.9	1079.0	897.7	1015.2	930.8	892.1	246.0	135.2	91.9	151.7	227.9	207.7
Lower Amur	2257.4	2308.7	2108.7	2229.9	2293.8	2474.9	2592.3	1197.0	1111.6	756.8	1145.0	1595.7	1603.0
Lower Ussurii	2003.4	1916.8	1840.3	2113.2	2093.7	2229.1	1773.4	645.0	398.0	326.2	536.2	721.4	695.2
Sovgaban	998.4	1008.1	972.1	1109.7	1353.5	1306.1	930.8	839.0	1170.4	938.7	1405.4	1597.1	1510.9
Urgal	4753.0	4735.3	3874.8	3788.3	3498.9	3490.6	2959.1	302.0	349.0	274.7	505.7	593.3	685.8
Total	*15021.6*	*14869.8*	*13143.9*	*13324.9*	*13766.9*	*13907.6*	*12781.2*	*4739.0*	*4617.8*	*3461.1*	*5779.8*	*7168.7*	*7289.4*

Table 10.2 Trend of harvest volume per hectare, by forest district in the Khabarovsk region (Unit: m^3/ha). (Source: Khabarovsk Regional Government, Khabarovsk Regional Forest Office)

Forest district	1948	1950	1953	1956	1959	1962	1965	1966	1968	1970	1972	1974	1976
Amgun	0.00	0.00	0.00	0.11	0.47	0.32	0.18	0.24	0.29	0.34	0.36	0.40	0.41
Komsomol	0.38	0.23	0.35	0.33	0.47	0.51	0.41	0.48	0.50	0.46	0.57	0.57	0.75
Kur/ulm	0.06	0.11	0.17	0.12	0.20	0.26	0.27	0.29	0.32	0.39	0.42	0.47	0.52
Nanai	0.15	0.18	0.30	0.34	0.53	0.48	0.48	0.70	0.61	0.73	0.62	0.79	0.71
Lower Amur	0.13	0.16	0.30	0.13	0.14	0.15	0.19	0.21	0.21	0.23	0.26	0.33	0.34
Lower Ussurii	0.34	0.56	0.52	0.67	0.65	0.67	0.68	0.75	0.68	0.68	0.65	0.63	0.61
Sovgaban	0.10	0.11	0.19	0.12	0.13	0.17	0.23	0.22	0.30	0.32	0.31	0.28	0.29
Urgal	0.08	0.03	0.06	0.04	0.05	0.05	0.02	0.05	0.35	0.71	0.80	0.95	0.95
Average	*0.17*	*0.18*	*0.26*	*0.22*	*0.30*	*0.30*	*0.29*	*0.34*	*0.41*	*0.51*	*0.54*	*0.60*	*0.62*
Amgun	0.39	0.42	0.36	0.37	0.42	0.52	0.58	0.30	0.32	0.23	0.50	0.57	0.62
Komsomol	0.84	0.73	0.60	0.55	0.60	0.50	0.66	0.22	0.20	0.16	0.28	0.30	0.28
Kur/ulm	0.48	0.46	0.42	0.43	0.49	0.47	0.24	0.11	0.08	0.04	0.04	0.14	0.18
Nanai	0.56	0.64	0.67	0.55	0.63	0.57	0.55	0.15	0.08	0.06	0.09	0.14	0.13
Lower Amur	0.37	0.37	0.34	0.36	0.37	0.40	0.42	0.20	0.18	0.12	0.19	0.26	0.26
Lower Ussurii	0.63	0.60	0.58	0.66	0.65	0.70	0.55	0.20	0.12	0.10	0.17	0.23	0.22
Sovgaban	0.31	0.31	0.30	0.34	0.41	0.40	0.28	0.26	0.36	0.29	0.43	0.49	0.46
Urgal	0.93	0.92	0.76	0.74	0.68	0.68	0.58	0.06	0.07	0.05	0.10	0.12	0.13
Average	*0.62*	*0.612*	*0.542*	*0.55*	*0.57*	*0.57*	*0.53*	*0.20*	*0.19*	*0.14*	*0.24*	*0.30*	*0.30*

characterized by the following. First, the Siberian railroad was completed in the early twentieth century. The railroad connecting the Siberian railroad and Komsomolsk city was completed in 1932. The railroad between Komsomolsk city and Sovgaban city was finished in 1947 as part of the Baikal Amur railroad (BAM railroad hereafter). Second, rivers were another important means of timber transport in this period. The Amur and Ussuri rivers and their tributaries were used to transport timber from logging areas to railroad loading yards. It was estimated that about 1 million m^3 of timber was transported by river in 1950. This had increased threefold by 1970 (Nistratov 2000). Thus, the Lower Ussuri and Komsomol FDs were located adjacent to railroad infrastructure, with a favored river system. This made them major timber consumption and production areas.

Logging methods during Period I were as follows. Originally, selective cutting was the major means for harvesting timber in the Khabarovsk region, because of a lack of skidding machinery. Timber with large diameters and favorable species for the market were selected for cutting. Heavy machinery for skidding began to be introduced in the 1950s and clear-cutting became the major harvesting method (Danilin 2000b). The introduction of heavy machinery made skidding possible in the non-snow season and logging could be done year round.

Degradation of forest resources in the FDs caused by high-intensity logging operations was already occurring in Period I. For example, Sheingauz indicated that in the Byazemskii district forest in the Lower Ussuri FD, coniferous resources rapidly decreased because of timber harvests in the 1950s and sustainable forest management was not achieved (Sheingauz 1965a, b, c). Btaraya Cidima village, which was developed as a center for forest development in the Byazemskii district forest in the 1930s, was deserted in the 1960s because of the exhaustion of exploitable timber resources (Sheingauz 1965a).

10.4 Period II: A High Level of Forest Development

10.4.1 Policy and Economic Background of Forest Development

The timber harvest in the Khabarovsk region rapidly increased during Period II. The volume of harvest in 1965 was 7.18 million m^3, rose to 12.42 million m^3 in 1970 and 15.14 million m^3 in 1976, and remained at a high level of production throughout the 1980s. The ratio of the Russian Far East area to total USSR timber production increased from 6.2 % in 1965 to 8.4 % in 1975 (Schiffer 1989).

Reasons for these trends are believed to be as follows. First, economic reform was terminated with the downfall of Khrushchev, and the economic situation grew out of confusion. The forest management organization and state forest industry were again separated in 1965, and forest management was administrated by the Ministry of Forestry. The state forest industry enterprise was administered by the Ministry of Forest Industry.

Second, development of the Russian Far East area became the major focus of the state economic plan. The Eighth Five-Year Plan stressed development of Siberia and the Russian Far East, and investment concentrated in natural resource development (Kumo 2003). This trend continued until the collapse of the USSR. In 1966, the Council of Ministers of the USSR issued the decree "On Development of Timber Harvest Industry from 1966 to 1970", which mandated further development of the timber harvest in Siberia and the Russian Far East. In 1972, the Council issued the decree "Long-term Forest Development Plan along BAM Railroad". This was adopted by the former USSR as a fundamental plan of forest development. These plans accelerated development in the aforementioned regions.

Third, timber export and supply to the Asian part of the USSR increased during Period II, which accelerated timber harvesting in the Khabarovsk region. For the former USSR, supplying timber to central Asian republics with scarce forest resources was an important issue and the Russian Far East regions were obliged to supply timber to those republics. Acquisition of foreign currency was also important for the USSR, and timber export to Japan increased rapidly during the period. The ratio of export to Japan to total USSR timber export increased from 23.4% in 1965 to 45.7% in 1970 (Schiffer 1989). Shiffer also estimated the log supply to the central Asian republics in 1985 at 0.5 million m^3, and the lumber supply at 0.5 million m^3. Using statistics from the Japan Timber Import Association, it is estimated that log exports from the Khabarovsk region to Japan were 2.17 million m^3.

10.4.2 Trend of Timber Harvest at the FD Level

In Period II, the most notable trend was that of the Urgal FD. This FD was a minor timber harvesting area in Period I, but drastically increased production in the 1960s. Both harvest amount and intensity far exceeded those of other FDs throughout the 1970s. However, these began to decrease in the 1980s. In the late 1970s, the harvest amount in the Urgal FD accounted for a third of total harvest in the region. For intensity of harvest, the Lower Ussuri, Nanai, and Komsomol FDs formed a second group behind the Urgal FD. The Ussuri remained at the same level throughout the period, while Nanai and Komsomol increased intensity during the 1970s and this remained constant afterward. The Kur/Ulm, Amgun, Lower Amur, and Sovgaban FDs formed a third group. For volume of harvest, the Lower Ussuri, Lower Amur, and Komsomol FDs followed Urgal FD.

The harvest trend may be summarized as follows. First, the Urgal, Lower Ussuri, and Komsomol FDs had the highest levels in terms of both volume and intensity of harvest. Second, harvest volume in the Lower Ussuri FD remained at almost the same level as the 1960s, while other FDs increased in the 1970s and then remained constant. As a result, the relative position of the Lower Ussuri FD declined.

The following are considered causes of these trends. First, the former USSR government signed an agreement with the North Korean government to lease forest resources and let Korean laborers do the logging. As compensation, 60% of the round wood they cut would be granted to the North Korea (Newell 2004). With this agreement, North Korea established four timber harvest enterprises between 1965 and 1967 along the BAM railroad, which made it possible to dramatically increase the volume of timber harvested in these remote areas.

Second, infrastructure such as forest roads and railroads was developed in other FDs, where untouched rich forest persisted and investment efficiency was high. Although the BAM railroad was completed in the early 1980s, completed sections were used sequentially to provide services and transport timber. Major roads connecting Komsomolsk and Khabarovsk cities, crossing the Nanai FD, were completed in the 1960s (Nistratov 2000). Along these railroad lines and roads, settlements for forest development were constructed. Infrastructure for such development such as forest roads was also built. These made it possible to increase timber production in the Urgal, Amgun, Kur/Ulm, Komsomol, and Nanai FDs.

Third, the Sovgaban and Lower Amur FDs were adjacent to a timber embarkation port and had advantages for exporting timber to Japan. Fourth, in the Lower Ussuri FD, forest development using existing infrastructure reached a limit and forest resources became degraded, as pointed out in the previous section. This caused the Lower Ussuri FD to drop in relative position within the region.

Although the volume of timber harvested was at a high level in Period II, the ratio of actual harvest to annual allowable cut (hereafter AAC) was about 40 % and did not appear to overharvest the Khabarovsk region overall. However, Krechetov et al. (1975) showed that the ratio of harvest volume to AAC differed greatly by district forest. Although 73 % of forest management organizations reported between 26 and 50 %, 6 % were between 76 and 100 % and 1 % exceeded 100 %. In Period II, AAC calculations included economically inaccessible forest resources. Taking the above into consideration, one can conclude that the active harvest area was overharvested in reality. For example, forest resources in the Urgal FD, with easy access to railroads, were degraded by overharvesting, and logging within 30 km of the railroad was banned in the late 1970s (Danilin 2000b).

Overharvesting of specific tree species was also a serious issue. Korean pine was the most valuable coniferous tree on the market, and it was mainly found in the southern Khabarovsk region where infrastructure was well developed. Harvesting concentrated on the Korean pine and its resources were reduced critically. Harvest limitations of this pine were already in effect by 1985 and, for its protection, harvesting was prohibited in 1990.

The introduction of heavy machinery was completed throughout the region in the 1960s, and clear-cutting became the standard type of logging operation. In the 1970s, new high-performance machinery developed in the USSR began to be introduced to logging operations. However, considerable damage to vegetation and soils resulted, because of the heavy weight of the machinery. The transport of timber changed from floating to railroad and/or road with development of these infrastructures. To protect fishery resources, the Khabarovsk regional government introduced Resolution No. 620, which restricted the floating of timber in 1978 and completely prohibited it in 1985 (Nistratov 2000).

10.5 Forest Development in Period III: The Transition Period

10.5.1 Policy and Economic Background of Forest Development

In 1991, the USSR collapsed and the Russian Federation was established. President Yeltsin carried out radical economic reform to change the planned economy to a capitalist one. With this reform, the Ministry of Forest Industry was abolished and state forest industry enterprises were privatized. Logging licenses were allocated based on open tender. Regarding the forest management organization, the Forest Service of the Russian Federation was established as the central forest administrative organization, but regional and local management systems remained unchanged.

Harvest volume during Period III was as follows. With the collapse of the USSR, the volume of harvest rapidly decreased to less than 4 million m^3 in 1998, 75 % below its peak in the 1980s. After reaching a minimum in 1998, the volume began to increase.

The reason for the rapid decrease was the collapse of the planned economy and confusion under economic reform. Price decontrol caused hyperinflation and the demand for timber products decreased rapidly. Although state forest enterprises were privatized, a lack of skilled managers produced a series of bankruptcies of these enterprises. In addition to these causes, factors inherent to the Khabarovsk region also led to a decrease. As mentioned earlier, the Russian Far East, including the Khabarovsk region, was a timber supply base for the central Asian part of the former USSR. However, because of soaring transportation costs and the USSR collapse, supply to these areas ceased (Kakizawa 2003b).

The harvest increase in 1999 was triggered by a ruble crisis, which had its inception in a budget crisis. With collapse in the value of the ruble, timber exports rapidly increased. This caused an increase in timber harvesting. In the Khabarovsk region, timber exports to China contributed greatly to accelerated timber export and harvesting. China introduced a natural forest protection policy in 1998 that reduced domestic timber supply, while China's timber demand increased because of strong economic growth. The gap between supply and demand was covered by timber imports from Russia (Yamane and Kakizawa 2003). Import volume rose from 0.36 million m^3 in 1995 to over 10 million m^3 in 2006. The Khabarovsk region was one of the major timber suppliers to China.

10.5.2 Timber Harvest Trend at FD Level

Decreases in timber harvest in the early 1990s and increases since 1998 were observed in every forestry region. However, in the Sovgaban, Lower Amur, Komsomol, and Amgun regions, the rate of decrease was relatively slight and the rate of increase was high. Harvest volume since 1998 was the greatest in the Sovgaban and Lower Amur FDs, followed by the Komsomol and Amgun FDs. Harvest intensity was highest in the Sovgaban, Komsomol, and Amgun FDs, followed by the Lower Amur and Lower Ussuri FDs. With intensity and volume considered together, the Amgun, Sovgaban, Komsomol, and Lower Amur FDs actively harvested timber in Period III, while the Urgal, Lower Ussuri and Nanai FDs were inactive. The order of FDs drastically changed in this period. The Sovgaban, Amgun and Lower Amur FDs ranked low in Period II but high in Period III, while the Nanai, Lower Ussuri, and Urgal FDs dropped in rank.

The major reason the Amgun, Sovgaban, Komsomol, and Lower Amur FDs were actively harvesting timber was because of increases in timber exports. With drastic shrinking of the domestic market under economic reform, the importance of foreign markets increased, so the recovery of timber harvests after 1999 was oriented toward timber exports. From the statistics of the Japan Timber Import Association, it is estimated that timber exports from the Khabarovsk region to Japan were 1.9 million m^3 of logs and 190,000 m^3 of lumber in 1995. Because total harvest volume in 1995 was 4.79 million m^3, exports accounted for almost half the harvest with consideration of utilization percentage. The Far Eastern Division of the Russian Academy of Science Economic Research Institute evaluated the supply-demand structure of the Khabarovsk region in 1999–2000, concluding that approximately 80 % of log production was exported (Far Eastern Division of Russian Academy of Science Economic Research Institute 2002). The Lower Amur and Sovgaban FDs face the Japan Sea and had advantages for export to Japan. The Amgun and Komsomol FDs were connected directly to export ports by railroad. For these reasons, those four FDs were most active in harvesting timber during the period.

The rapid decrease for the Urgal FD is attributed to cancelation of the agreement with North Korea. Logging activities by that country were criticized severely internationally because of disregard for laborer rights and environmental destruction. The agreement with North Korea was reexamined after the collapse of the USSR and logging activities in Urgal FD were halted. The Lower Ussuri FD, which had been one of the most active timber harvesting areas, continued to drop in position because of serious degradation of forest resources. As loggers had to move to more remote areas to seek rich resources, transportation costs increased and logging was no longer economically feasible.

In this chapter, the author has repeatedly shown that forest development in the Khabarovsk region was not sustainable. The following is an example of the results of unsustainable forest development in the Lower Ussuri FD (Far Eastern Division of Russian Academy of Science Economic Research Institute 2002). Lazo County is just south of Khabarovsk city and has a border with China along the Ussuri River. The Siberian railroad runs through the western part of the county, and the Ussuri River and its tributary were used for timber floating. The county is adjacent to areas of high timber consumption and has advantages of transportation infrastructure. For this reason, timber harvesting became active in the 1920s. In the 1930s, the Obor state forest enterprise was established at Sita village, for which a logging railroad to carry timber was constructed as a branch line of the Trans-Siberian Railway. From the mid 1950s to mid 1960s, timber harvest volume remained between 700,000 and 1 million m^3, which was not only the highest in the Khabarovsk region but one of the largest forest product enterprises in the USSR during that period. Timber harvests were the leading product of the local economy. For example, 70 % of the population of Sita village was employed by the enterprise (Far Eastern Division of Russian Academy of Science Economic Research Institute 2002). However, such a high level of timber harvesting together with improper logging methods destroyed forest resources, and the volume of timber harvest has dropped rapidly since the late 1960s. The volume harvested in the mid 1970s was below 100,000 m^3 and the local economy was greatly devastated. Because Sita village was dependent on this enterprise, depopulation and unemployment became serious issues. Maintenance of infrastructure such as the road system and provision of public services such as heating, which was managed by the enterprise, became difficult. In 2001, there were 466 unemployed and 633 employed people in the village.

Nevertheless, there are still rich forest resources in the eastern part of Lazo county, although investment in a road network and basic infrastructure are required. The regional government offered these resources to international bidding, aiming to introduce foreign enterprises that had sufficient investment ability to develop forest resources. Bidding in 1998 resulted in Rimbunan Hijau, a Malaysian multinational company, receiving a license for an AAC of 400,000 m^3 (Newell 2004).

10.6 Conclusions

In this chapter, forest development of the Khabarovsk region after World War II was analyzed. From the standpoint of forest development sustainability, the following conclusions are made.

First, although the total actual harvest was well below the AAC, harvest intensity varied by FD and timber harvests tended to concentrate in certain FDs. These were the Lower Ussuri and Komsomol FDs in Period I, Urgal, Lower Ussuri, and Komsomol FDs in Period II, and Sovgaban, Komsomol, Amgun, and Lower Amur FDs in Period III.

Second, FDs in which timber harvests concentrated did not sustainably manage forest resources. Restriction of logging activities in the Urgal FD and the prohibition of final cutting of Korean pine are examples of efforts required to repair damage caused by unsustainable forest development. The decline in relative position of the Lower Ussuri FD was because of resource degradation under unsustainable forest development.

Third, the sustainability of local societies was not considered in forest development. With resource degradation, timber enterprises were shut down and communities were left devastated and suffering from high unemployment.

Forests that were rich in resources, surrounded by effective infrastructure, and adjacent to areas of high timber consumption remained foci of development and were subject to degradation of forest resources. Following the exhaustion of exploitable resources, forest development bases moved to other areas. Because of this, local societies were devastated. Consequently, sustainable forest management should be reconsidered and local societies and economies taken into account.

References

Bradshaw M (1991) Industrial restructuring and Soviet regional development. In: Bradshaw M (ed) The Soviet Union, a new regional geography? Halsted Press, New York, pp 1–14

Danilin A (2000a) Histrory of forestry administration. In: Danilin D (ed) Forest and forestry in the Khabarovsk region. Khabarovsk Publishing Firm, Khabarovsk, pp 179–252 (in Russian)

Danilin A (2000b) Final cutting. In: Данилин A (ed) Forest and forestry in the Khabarovsk region. Khabarovsk Publishing Firm, Khabarovsk, pp 179–252 (in Russian)

Efremov Д (ed) (1989) Forest resources of the far eastern economic region: condition, use, regeneration. Forest Research Institute, Khabarvsk (in Russian)

Far Eastern Division of Russian Academy of Science Economic Research Institute (2002) The report on "developing a forest conservation strategy for the Russian Far East". In: Kakizawa H, Inoue M (eds) Russia country report 2001. IGES, Hayama

Federal Forest Service of Russia (1998) Two hundred year of forest department, vol 2. BNIILC, Moscow (in Russian)

Kakizawa H (2003a) Forest resource. In: Kakizawa H, Yamane M (eds) Russia—current state of forestry. J-FIC, Tokyo, pp 36–55 (in Japanese)

Kakizawa H (2003b) Forest industry in transition. In: Kakizawa H, Yamane M (eds) Russia—current state of forestry. J-FIC, Tokyo, pp 121–142

Krechetov H, Chorishev B, Sheingauz A (1975) Fundamental direction of forestry in regions with rich forest resources. Forest Industry Publishing, Khabarovsk

Kumo K (2003) Regional development and demographic shift of former USSR and Russia. University Education Press, Tokyo (in Japanese)

Newell J (2004) The Russian Far East: a reference guide for conservation and development. Daniel & Daniels, McKinleyville

Nistratov B (2000) Volume of forest use, technical and silvicultural aspect of logging operation. In: Danilin Ð (ed) Forest and forestry in the Khabarovsk region. Khabarovsk Publishing Firm, Khabarovsk, pp 264–268 (in Russian)

Nove A (1992) An economic history of the USSR. Penguin Books, New York

Sheingauz A (1965a) Forest dynamics in Korean pine—broadleaf forests in the Ussuri river Basin, Ulahinsk and Vyazemskii Lespromkhoz. Far Eastern Branch of Academy of Science, USSR, Khabarovsk (in Russian)

Sheingauz A (1965b) Change of forest cover in Vyazemskii area for 100 years. Problems of Geography geography in the Far East 3. Khabarovsk publishing Firm, Khabarovsk, pp 76–88 (In Russian)

Sheingauz A (1965c) Development of forest resources of Korean Pine—broadleaf forest under selective cutting operation. Bull Far East Forest Res Inst 7:103–116 (In Russian)

Schiffer (1989) Soviet regional economy. St. Martin's Press, New York

Shividenko A, Nilsson S (1996) Expanding forest but declining mature coniferous forest. IIASA Working Paper WP96-59. IIASA, Laxenburg

Yamane M, Kakizawa H (2003) Expanding timber trade. In: Kakizawa H, Yamane M (eds) Russia—current state of forestry. J-FIC, Tokyo, pp 143–167 (in Japanese)

Chapter 11
Land-Use Dynamics in the Amur River Basin in the Twentieth Century: Main Tendencies, Driving Forces and Environmental Consequences

Natalia V. Mishina

Abstract Active settlement and economic development in the Amur Basin started relatively late, in the middle of the nineteenth century. However, this late start of colonization was compensated by a high rate of economic development, which resulted in substantial transformation of the natural environment. In this chapter, basic tendencies of land-use dynamics in the Amur Basin over the last century are considered, using various data including cartographic, statistical, and literary. Comparative analysis is done for the Russian and Chinese portions of the basin, because they form more than 90 % of its area and have close ecological and economic interrelations. Increases in population and economic development of the area are considered basic factors of land structure change. The emphasis is on study of the dynamics of cultivated and forest lands, which cover more than 50 % of the Chinese part of the basin and greater than 60 % of the Russian part. The greatest environmental consequences of land-use changes in the Amur Basin during the twentieth century are analyzed.

Keywords Land use • Land cover • Russian Far East • Amur River Basin

11.1 Main Tendencies in Land-Use Dynamics in the Amur River Basin During the Twentieth Century

The Amur is one of the longest rivers in the world, with a drainage basin area exceeding 2 million km^2. More than 90 % of this area is within Russia and China (49.3 % and 42.2 %, respectively), and 8.5 % within Mongolia. In recent decades, different aspects of land use in the basin were studied intensively (Himiyama 1997; Liu et al. 2004; Karakin and Sheingauz 2004; Baklanov and Ganzei 2004; Ganzei and Mishina 2005; Wang et al. 2005, 2006; Ye and Fang 2009). However, a complete cartographic assessment of land-use dynamics for the entire basin has not been made. Therefore, creation of basin land use maps at scale 1:25,00,000 became a task

N. V. Mishina (✉)
Pacific Geographical Institute FEBRAS, 7 Radio Street, 690041 Vladivostok, Russia
e-mail: mishinata@yandex.ru

S. Haruyama, T. Shiraiwa (eds.), *Environmental Change and the Social Response in the Amur River Basin,* International Perspectives in Geography 5,
DOI 10.1007/978-4-431-55245-1_11

in the framework of the international Amur-Okhotsk Project (Research Institute for Humanity and Nature, Kyoto, 2005–2009).

The map "Current Land Use of the Amur Basin" was compiled during 2005–2006, based on data interpretation from Landsat Thematic Mapper satellite images (2000–2001). This facilitated analysis of present land use in the basin on a unified cartographic platform (Ganzei et al. 2007). A second map reflecting basin land use during 1930–1940 was completed in 2008. Topographic maps of different scales (1:100,000 to 1:1,000,000) issued in various years in the USSR, Japan, and the United States were used as the map basis (Ganzei et al. 2010).

For analysis of land use structure changes in the Amur Basin from the mid 1930s to the early twenty-first century, data of land use for two periods were recalculated in accord with a common legend. According to the data obtained, there were essential changes of land structure over the 70-year period. For the basin as a whole, changes of forestlands, meadows, wetlands, and mountain tundra were negative, and their shares decreased 5.5, 5, 63, and 0.4 %, respectively. Proportions of lands covered by sparse forests and bushes slightly increased, while expansion of arable lands was greater (11.3 %). The area of cut and burned-out forests also increased (generally, by 0.8 %) (Ganzey et al. 2010).

These tendencies became apparent on both sides of the frontier, but at different intensities. In the Chinese territory the forestlands shrunk by only 1 %, but areas of meadows and wetlands decreased by 20 %. In the Russian part of the basin, the share of meadows and wetlands decreased by 8 %, while that of forestlands dropped by more than 10 % (Table 11.1).

Cultivated land, including rice paddy fields, has expanded in the Chinese part of the basin by almost 19 %, occupying more than 30 % of total area in 2000–2001. On the Russian side, the area of cultivated land increased over the 70 years by 7 %, and lands occupied by bushes, sparse forests and burned areas increased considerably. On both sides of the boundary, lands with settlements and forest logging expanded (Table 11.1). Thus, a reduction of natural ecosystems (forests, meadows, and wetlands) and extension of cultivated and settlement lands, as well as logged and burned areas, were the major tendencies of land-use dynamics during the twentieth century, on both sides of the frontier.

11.2 Main Factors of Land-Use Dynamics in the Amur River Basin

The main factors of land-use dynamics in the basin are population growth and economic development. Active economic development on both sides of the national boundary began relatively late (second half of the nineteenth century) and was related to exploitation of the rich natural resources, i.e., land, forest, mineral raw materials, freshwater, and others. Participation and interaction in this process by various countries (Russia, China, and Japan) striving to achieve their geopolitical interests in the region became a unique feature of its economic development.

Table 11.1 Land use/land cover structure of Chinese and Russian portions of the Amur river basin in various years (%)

Land use/cover type	China			Russia		
	1930–1940	2000–2001	Change	1930–1940	2000–2001	Change
Forest land	43.3	42.2	−1.1	66.1	55.8	−10.3
Sparse forest	3.3	4.0	0.7	4.6	10.5	5.9
Bushes	2.6	3.9	1.3	3.3	8.1	4.8
Grassland	22.7	10.3	−12.3	4.6	2.4	−2.1
Dry land	14.5	30.6	16.1	1.2	8.0	6.8
Paddy field	0.1	2.7	2.7	0.0	0.2	0.2
Wetland	12.9	5.2	−7.7	15.4	9.5	−5.9
Lakes & reservoirs	0.3	0.6	0.3	0.6	0.7	0.2
Urban land	0.0	0.2	0.2	0.0	0.1	0.1
Forest cutting area	0.0	0.2	0.2	0.3	0.7	0.4
Burned-out forest	0.0	0.1	0.1	1.7	2.6	0.9
Mountain tundra	0.0	0.0	0.0	2.1	1.3	−0.8
Unused land	0.3	0.0	−0.3	0.1	0.1	0.0
Total	100	100	0	100	100	0

Economic development of the border areas of Northeast China (Northern Manchuria) in the second half of the twentieth century passed through two stages, namely, that of Russian influence during 1896–1930 and of Japanese influence during 1931–1945. The first stage was tied to construction of the Chinese Eastern Railway (CER) during 1896–1903. This road, constructed and managed by Russians based on a lease agreement with the Chinese government, was initially intended for realization of Russian economic and strategic goals. However, the road eventually made new Manchurian territories accessible to Chinese settlers and oriented a rapidly growing regional economy toward foreign markets. After the Russo-Japanese War in 1904–1905, Japan expropriated the southern part of the CER and Manchuria was divided into two zones of influence. South Manchuria comprised Kwantung Leased Territory, Mukden Province, and Southern Girin Province, and was mainly influenced by Japan. The zone of Russian influence, known as Northern Manchuria, consisted of Amur Province with Barga and Northern Girin Province (Frizendorf 1929). Northern Manchuria was approximately within the borders of the Chinese part of the Amur Basin.

In the 1920s, the Russian influence in Manchuria lessened, while Japan achieved its interests ever more successfully. In 1931, Japan began to occupy Manchuria and, in 1932, the state of Manchukuo was established, subordinate to the Japanese government. Through the mid 1940s, trade in Manchukuo was significantly reoriented to the Japanese market. Japanese capital became dominant in all branches of the economy. Military industrial facilities were built, and there were increases in commercial mineral extraction, extensions of road networks, and intense agricultural development.

The situation radically changed after 1949, when the People's Republic of China (PRC) was established, and predominantly internal forces represented by the Communist Party came to determine economic development in the region. The government of the country created an administrative-command system of economic management on the example of the Soviet Union, and the regional economy was reoriented toward satisfying regional requirements and needs.

Before the early 1990s, economic development in the Russian area was mainly determined by internal factors. Military-strategic significance of the Southern Far East has shaped the trend and intensity of that development in many aspects over the last 150 years. During this time, the concept of the region as a Russian outpost on the Pacific Ocean and in Northeast Asia remained fundamental for formation of central government economic policy in the Russian Far East. At the same time, regional economic development largely depended on assessments of the military importance of the Far East by national leadership during various periods. This changed following the world geopolitical environment and internal political situation of Russia, plus the state of relations with China, Japan and the United States.

In the Russian Far East, economic response to external influence was weak because of the insignificant economic development. From the beginning of the 1920s to end of the 1980s, responses to external economic impacts under the state-planned economy were rigidly regulated and sanctioned by the state, with consideration of the existing economic and political situation. The period from the beginning of the 1920s to mid 1930s, when the Far East strongly developed foreign trade, was transitional because the expansion of foreign economic activity was aimed at receipt of additional funds for recovery and development of the economy of the new Soviet state. The period of total control terminated with the USSR collapse in 1991. Beginning in the early 1990s, economic development in the Far East was greatly exposed to external influence, which was expressed by dependence of the regional economic system on the import and export of various products.

External influence was significant in the dynamics of development and use of agricultural lands in Manchuria during the 1900s–1930s (Mishina 2010), and of forestlands in the Southern Far East during 1990–2000s (Sheingauz 2004, 2005a, 2006, 2008; Antonova 2007; Mishina 2008; Yamane 2010). At the same time, however, the role of internal political, military-strategic, economic and socio-demographic factors for twentieth century development of the Russian and Chinese parts of the Amur Basin was more important.

Delimitation of the Russian and Manchurian territories was complete by 1860. According to the administrative-territorial division of Manchuria at that time, it included three provinces, two of which—Amur (or Heilongjiang) and Girin (or Kirin)—occupied the Chinese part of the Amur Basin. Prohibitions on migration of Chinese to Manchuria were canceled in 1878. Together with construction of the CER, this resulted in intense development of Manchuria by Chinese immigrants. Early in the twentieth century, the population of Manchuria reached about 13 million, 4.5 million of which resided in the Amur Basin (Table 11.2).

By the early 1930s, population in the Chinese part of the basin had increased to 14.2 million. The major growth in population was in Girin Province (the greater

Table 11.2 Population of Manchuria (1000 people) in various years. (Sources: Bank of Chosen 1920; Japanese Railways Office 1913; Manchuria Railway Office 1929; Second Report on Progress in Manchuria 1931)

Oblast/Province	1906	1908	1916	1927	1929
All Manchuria	13265.88	15834	20112.2	27512.8	29197.92
Amur province	1455.66	1456	2494	5154.9	5133.73
Kirin province	3047.08	4222	5638.7	8766.8	9075.63
Mukden province	8763.15	10156	11979.4	13591.1	14988.56

Fig. 11.1 Scheme of administrative division of Manchukuo in the late 1930s. Legend: *1* boundary of the Amur River Basin, *2* state boundaries, *3* railways, *4* Manchukuo capital, *5* capitals of Manchukuo provinces

part of present-day Jilin Province) and the inter-stream area of the Amur, Ussuri and Sungari rivers. From 1906 to 1929, population density there increased from 14.5 to 43.3/km^2. Amur Province remained the least populated, although its population density increased nearly 3.5-fold within 20 years. A tremendous inflow of colonists to Girin and Amur provinces in the 1920s was related to the availability of considerable reserves of uncultivated fertile lands (Economic History of Manchuria 1920).

After establishment of the Manchukuo state in 1932, reform of the administrative-territorial division was carried out, and there were eight provinces in the Chinese part of the Amur Basin (Fig. 11.1). In 1937, population in this part reached 14.8 million (Japan-Manchuokuo Year Book 1939). The highest population densities (20–60/km^2) were on the Great Manchurian Plain (Songliao Plain), the Chinese portion of the Khanka Lake basin and, adjacent to it, parts of the Ussuri River basin and Razdolnaya (Suifenhe) River valley. Mountainous territories of the Little and Great Khingan Mountains, swampy Sanjiang Plain, and inter-stream area of the Amur and Ussuri rivers remained sparsely populated (1–20/ km^2).

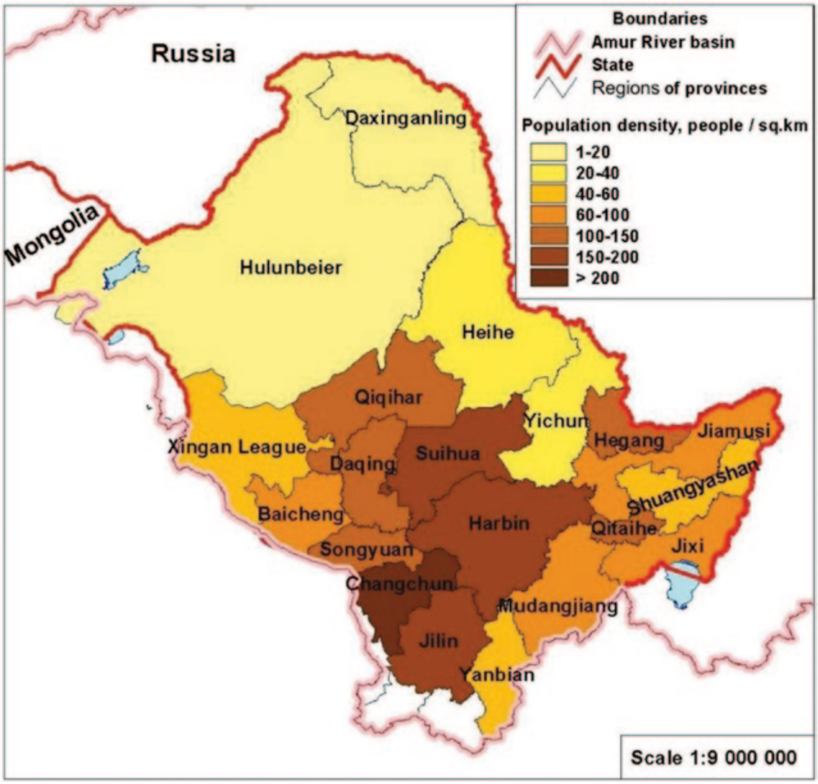


Fig. 11.2 Population density in the Chinese part of the Amur River Basin, 2010. (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011; Inner Mongolia Statistical Yearbook 2011)

Within the present Chinese provinces, population change from 1952 to 2010 was as follows, in millions: 10.1–38.3 in Heilongjiang Province; 10.6–27.2 in Jilin Province; and 7.2–24.7 in the Inner Mongolia Autonomous Region. The number of people residing within the Chinese part of the Amur Basin in 2010 was about 61.5 million (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011; Inner Mongolia Statistical Yearbook 2011). Thus, the population in this area increased four-fold over nearly 70 years. Population density varied widely, from 11/ km^2 in the Daxinganling region (Heilongjiang Province) to 370/km^2 in the Changchun region (Jilin Province) (Fig. 11.2). However, major changes in population distribution were not noted. Maximum population densities remain in areas on the Songliao Plain and surrounding hilly terrain, and Khanka Lake and Sanjiang Plains. Lowest densities are in the northern and western mountain-forest, steppe, and semi-desert areas.

The population in the Russian part of the basin was always much smaller than in the Chinese part. Until 1862, the majority of migrants along the Amur and Ussuri rivers in the Far East were soldiers and Cossacks. Defense and economic development

Table 11.3 Population in the Russian part of the Amur Basin (thousand people) in various years. (Source: Atlas of the Asian Russia 1914; Nersesov 1926; Tarkhov 2005)

Oblasts/provinces	1897	1905	1911	1923
Amurskaya	120.3	143.7	286	392.2
Primorskaya	189.5	246.8	524	634.4
Zabaikalskaya	405.0	–	–	547.5

of these regions were their primary tasks. Peasant colonization of the region began, and construction of the Trans-Siberian Railroad during 1891–1916 especially contributed to its increase. Population in the Russian portion of the basin from the end of the nineteenth through early twentieth centuries was about 700,000–750,000. By 1923, this population doubled compared with 1897. An increase in residents of Primorskaya Oblast (area of modern-day Primorskii Krai and southern Khabarovskii Krai) was particularly large (Table 11.3).

According to a population census in 1939, more than 3.1 million people resided in the Russian portion of the basin, with an extremely irregular population distribution. From the initiation of economic development there, the major share of migrants concentrated along the national boundary on the banks of the Amur and Ussuri rivers, on the Zeya-Bureya and Khanka Lake plains, in the valleys of the Shilka and Argun rivers in Transbaikalia Territory, and other river valleys favorable for settlement and crop farming along railways and in the southern part of the present Primorsky Krai (Nersesov 1926).

In subsequent years, regional population growth was not as great as in the first decades of the twentieth century. This population maximized in 1992, at 6.6 million (*Minakir and Mikheeva* 1999; Encyclopedia of Transbaikalia 2000). Then, under the economic crisis conditions of the 1990s, the population began to decline. At present, the southern Far East and Transbaikalia Territory are among the least populated regions in Russia. In 2010, average population density in the Russian part of the Amur Basin was only 3/km^2. This value, like the total population, decreased relative to 1992 (Table 11.4).

In all administrative territories of the Russian part of the basin, the population distribution is, as before, very irregular (Fig. 11.3). Within the southern Far East, three demographic zones (south, central, and north) were identified by considering population density, duration of settlement, population dynamics, and living conditions (Conservation Action Plan for the Russian Far East Ecoregion Complex 2003). From the southern to northern zone, population density decreased from 15/0.5 per km^2, and the number of large settlements declined rapidly. The southern zone comprises about 20 % of the southern Far East, but has up to 80 % of its population and a considerable portion of the natural and economic potential. This zone is also characterized by well-developed transportation and social infrastructure, based on the Trans-Siberian Railroad, major auto roads, and a relatively dense network of settlements, many of which were established in the late nineteenth to early twentieth centuries.

The central demographic zone comprises about half the southern Far East area, but only about 20 % of its population. The major forest resources of the region are

Table 11.4 Dynamics of population and its density in the Russian part of Amur Basin. (Source: Russian Far East: an Economic Potential 1999; Encyclopedia of Transbaikalia 2000; Far Eastern Federal Region 2011b; Population of Zabaikalskii Krai: http://chita.gks.ru/digital/region1/default.aspx)

Territory	Population, $\times 10^3$ people, at the end of year		Change in population in 1992–2010, $\times 10^3$ people	Area, $\times 10^3$ km^2	Population density, People/km^2	
	1992	2010			1992	2010
Primorskii Krai	2309.2	1953.5	−355.7	164.7	14.0	11.9
Khabarovskii Krai + EAO	1855.4	1519.6	−335.8	787.6	2.3	1.9
Amurskaya Oblast	1075.2	827.8	−247.4	361.9	3.0	2.3
Zabaikalskii Krai	1318	1108.3	−209.7	431.9	3.0	2.6
Total	6557.8	5409.2	−1148.6	1873.4	3.5	2.9

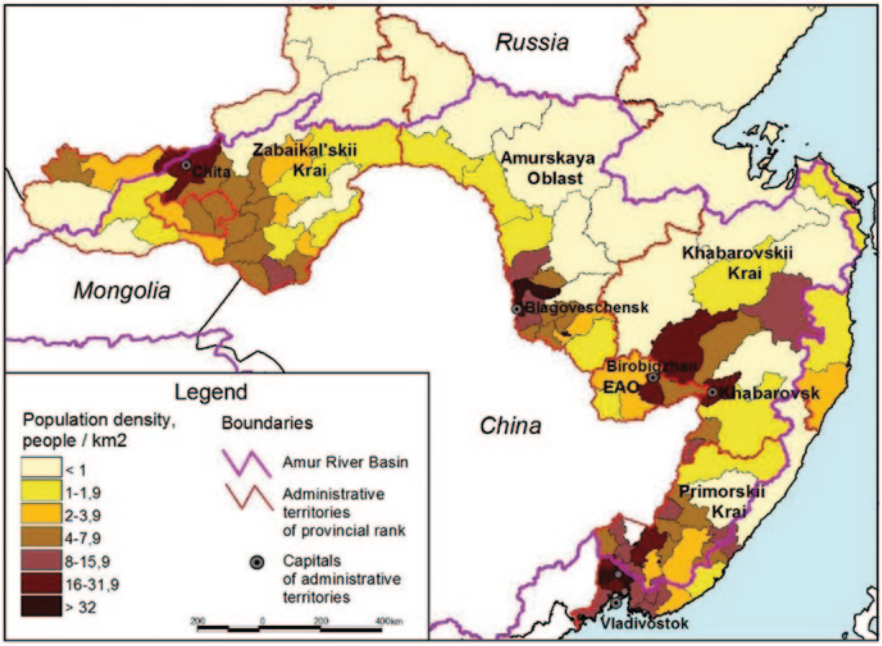


Fig. 11.3 Population density in the Russian part of the Amur River Basin, 2010. (Socioeconomic situation in municipal districts of Zabaikalskii Krai 2010; Amursky Statistical Yearbook 2011; Environmental conditions of Khabarovskii Krai in 2010 2011a; Statistical Yearbook of Primorskii Krai 2011; Passport of Evreiskaya Avtonomnaya Oblast 2011)

in this zone. The north demographic zone encompasses only 20% of the southern Far East area and about 0.4% of its population (Conservation Action Plan for the Russian Far East Ecoregion Complex 2003).

Another distinctive feature of resettlement in the Russian part of the Amur Basin is a high level of urbanization. In 2007, the proportion of city dwellers in the total population reached 64% in Zabaikalskii Krai, 75.4% in Primorskii Krai, 80.5% in Khabarovskii Krai, 65.4% in Amurskaya Oblast, and 66.2% in the Evreyskaya Autonomnaya Oblast (EAO) (Regions of Russia 2009). The greater part of cities and large settlements is within the south demographic zone and, as a rule, near the border between Russia and China. The same area in the Russian part of the basin has the greatest anthropogenic impact on the natural environment. Here there is the widest array of environmental problems, of varying severity. Anthropogenic impact in the less settled and less economically developed northern areas is not as extensive. Nonetheless, the anthropogenic influence and its adverse ecological consequences at certain locations may be great (for example, in cases of timber-cutting and mining).

Analysis of the history of settlement and development of the Chinese part of the Amur Basin allows determination of a few demographic and natural-economic zones. As in the Far East, the south zone of development in the Chinese territory is associated with plains and valleys of major rivers, whose settlement and agricultural exploitation triggered the economic colonization of the entire region. This zone covers the current Harbin, Qiqihar, Daqing, and Suihua regions in Heilongjiang Province, plus the Changchun, Jilin, and Songyuan regions in Jilin Province (Fig. 11.3). At all stages of development, these areas contained the largest parts of the population, major built-up areas and production capacities, as well as higher-density traffic arteries and social infrastructure. These areas formed the base for further advances of population and the economy in areas of new development. Currently, about 25% of the area, 63% of the population, and 60% of all cultivated lands in the Chinese portion of the basin are in the aforementioned regions. The share of GDP production by agriculture, forestry, animal husbandry, and fishery is 74% in Heilongjiang and 61% in Jilin provinces (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011).

The southern demographic-economic zone, with the longest history of economic development, has had considerable anthropogenic impact and is characterized by strong transformation of the natural environment. This zone has little preservation of natural flora and fauna, and has heavy pollution of air, water, and soil. The Sanjiang Plain, basins of Khanka Lake and Ussuri River, East Manchurian Mountains, Little and Great Khingan Mountains, which were all intensely developed in the second half of the twentieth century, have experienced the same environmental problems. However, as a whole, these differ in that they have less anthropogenic impact, more numerous preserved natural complexes, and better air and water quality than the southern demographic-economic zone of the Chinese part of the Amur Basin.

The population of the entire basin has increased by a factor of 13 over the last 100–110 years, from 5.25–67 million. At the end of the nineteenth to the beginning of the twentieth centuries, 14% of the population was in the Russian part. By 2010, this declined to 8 %. This population increased 7.3-fold over the study period, while that in the Chinese portion increased 13.6 times. In the latter portion, the population increased more in the second half of the twentieth century, whereas the increase in the Russian portion was greater in the first half. On both sides of the national boundary, the population is very irregularly distributed, and areas of maximum and minimum population persist from the beginning of regional colonization. These demographic-economic zones vary substantially by amount of transformation of natural complexes and severity of environmental problems. Because maximum changes in land use over the last century were related to areal increases of agricultural lands and decreases in forestlands, the dynamics of these land types and associated environmental consequences are addressed in more detail in the following.

11.3 Dynamics of Cultivated Lands in the Amur River Basin and Environmental Consequences

On both sides of the national boundary in the basin, economic development has been primarily related to the resettlement of peasants. The increase in population was accompanied by great expansion of cultivated lands. Farming of arable land significantly affects the state of the environment through land disturbance and destruction of local ecosystems. This occurs through transforming native natural complexes into anthropogenic agricultural landscapes. The influence on lands used as hayfields and pastures has been less intense, and mainly involves alteration of their individual natural components, i.e., soils, biota, and groundwater.

11.3.1 Historical Overview of the Dynamics of Cultivated Land

According to statistical data, the area of cultivated lands in Manchuria was 6.8 million ha in 1908 (Economic History of Manchuria: compiled in commemoration of the decennial of the Bank of Chosen 1920). This figure nearly doubled by 1929, approaching 13.1 million ha or about 17 % of total area. By 1936 (Manchukuo), it reached 15.3 million ha (Fig. 11.4), of which about 9.5 million ha were in the Amur Basin. The largest shares were in the provinces of Pinkiang (~ 23 %), Kirin (~ 20 %) and Lunkiang (~ 14 %) within the fertile Songliao Plain. North Manchuria was also considered a basic source of promising lands for agricultural development. In particular, 86 % of cultivable area was undeveloped in Sankiang Province, 55 % in Mutankiang, 75.5 % in Lunkiang and ~ 50 % in Pinkiang (Fig. 11.1). Partly because of development of these lands, cultivated areas of Manchukuo were estimated at 17.9 million ha in 1940 (Fig. 11.4).

After formation of the PRC in 1949, a new wave of agricultural development in the Chinese section of the Amur Basin began, with the primary objective of food production increase to supply the needs of all China. From 1952 to 1957, 1.1 million

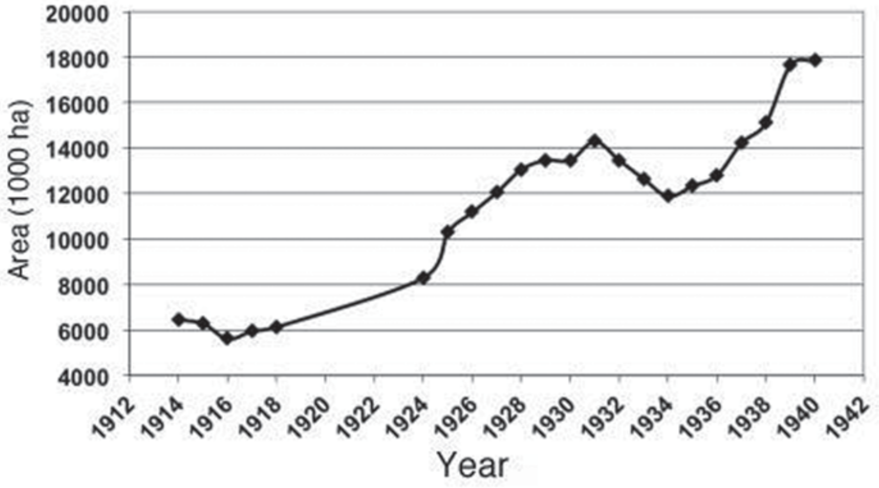


Fig. 11.4 Dynamics of sown area in Manchuria. (Manchuria: A Statistical Survey of its Resources, Industries, Trade, Railways and Immigration 1929; Japan-Manchuokuo Year Book 1939; Manchuokuo Year Book 1942)

ha of virgin land in Heilongjiang Province were put into use. This comprised 20 % of all virgin land in the country. Basins of the Ussuri and Nunjiang rivers and of Khanka Lake became key areas of new land development. Cultivated land in Heilongjiang province reached about 7.3 million ha in 1957. In Jilin Province, about 3.4 million ha were cultivated in 1952 (U et al. 1963). Additionally, a policy of active agricultural development of cultivable lands in the Chinese part of the Amur Basin continued in subsequent years. By 2010, total sown area attained 14.25 million ha in Heilongjiang Province and 5.2 million ha in Jilin Province (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011).

In the second half of the twentieth century, particular attention was given to rice growing, so irrigation networks and paddy fields were created. In Jilin Province, the area of paddy fields increased during 1949–1958 from 85,000 to 358,000 ha. In Heilongjiang Province in 1957, such fields occupied 287,000 ha (U et al. 1963). In 2010, rice plantations of Jilin Province reached 670,000 ha (80 % of which are within the Amur Basin), and in Heilongjiang Province they comprised 2.9 million ha (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011).

According to statistical data, cultivated land in the Chinese part of the Amur Basin increased from 9.5–10 million ha (Japan-Manchukuo Office 1939) to 20.5 million ha (Heilongjiang Statistical Yearbook 2006, 2011; Jilin Statistical Yearbook 2006, 2011) between the mid 1930s/ early 1940s and 2010. The major expansion of cultivated lands was in Heilongjiang Province. As in the mid 1930s, there were considerable areas of such land on the central Manchurian Plain. Portions of cultivated lands within the Qitaihe and Suihua regions in Heilongjiang Province reached 45 %, while those in the Songyuan and Changchun regions in Jilin province were 44 and

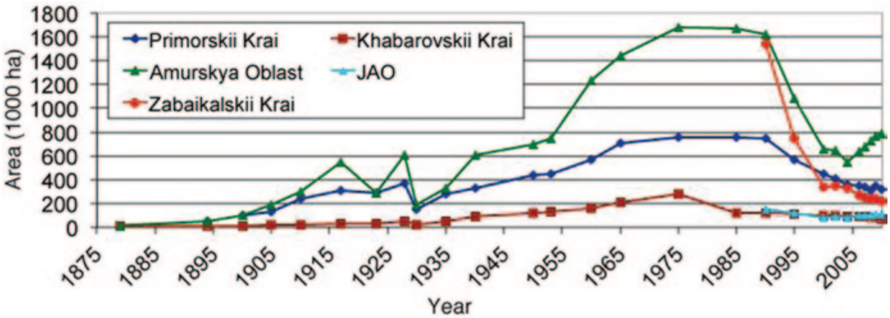


Fig. 11.5 Dynamics of sown areas in the south of the Russian Far East and Transbaikalia. (Tibekin 1989; Regions of Russia 2008; Some Agricultural Statistics of Zabaikalskii Krai 2010; Socio-economic Situation in Cities and Districts of Khabarovskii Krai in 2010, 2011; Socioeconomic Situation in Municipal Formations: Statistical survey 2011; Socioeconomic Characteristics of Birobidzhan City and Districts of Evreiskaya Avtonomnaya Oblast 2011; Municipal Formations of Amurskaya Oblast 2011)

54 %, respectively (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011).

In the Russian part of the Amur Basin, the majority of cultivated land was on the southern plains of Amurskaya Oblast, Primorskii and Khabarovskii krais, and Evreiskaya Avtonomnaya Oblast (EAO). This is the main agricultural area of the Russian Far East, where wheat, oats, corn, soybean, vegetables and potatoes are raised; rice is cultivated in southern Primorskii Krai (Karakin and Sheingauz 2004).

Active agricultural development in the Russian part of the basin began in 1860. By 1900, the area under crops in the southern Russian Far East (RFE) was 216,000 ha (Tibekin 1989). Increase of cultivated land was slow. One million ha was exceeded only in the second half of the 1920s, and the maximum 4.2 million ha was attained in the late 1980s to early 1990s. There was a significant expansion of sown area in Amurskaya Oblast during the second half of the twentieth century; over 1954–1964, more than 700,000 ha of virgin and fallow lands were put to use there (Tibekin 1989).

During the economic crisis and economic system restructuring in the 1990s, cultivated land in the Russian part of the basin decreased by a factor of two and was 1.5 million ha in 2010 (Fig. 11.5). There is currently slight but stable growth of sown area in Amurskaya Oblast and EAO only. Overall, despite expansion of cultivated land in the Russian part during the second half of the twentieth century, agricultural development in the region was extensive and inefficient, and was realized mostly because of governmental subsidies (Simonov and Dahmer 2008; Karakin 2009).

During agricultural development of the Russian part of the Amur Basin, areas with the best conditions for crop production were developed first. These were the Zeya-Bureya and Khanka Lake plains, valleys of the large rivers (Ussuri, Bikin, Razdolnaya, and Bureya), and the southern Chita region of Dauriya. However, land appropriate for crops (fertile, with optimal hydrologic conditions and geomorphologic location) was not extensive. The majority of land considered the base for agricultural colonization in the region required improvement, which was generally drying, fertilizer application, and chalking. Intense development of such lands began in the 1950s, peaking in the 1960–1980s. A total of 592,000 ha of drained land and 125,400 ha of irrigated land were put to use in the southern Far East from 1966 to 1985. Drained land was 40 % in Amurskaya Oblast, and 75 % was irrigated lands in Primorskii Krai (Tibekin 1989). More than 60 % of all reclaimed lands of Primorskii Krai were on the Khanka Lake plain, where rice production was actively developed through the end of the 1980s. Toward the end of the 1990s, the share of arable land under rice was 4 % of total sown area in the Russian part of the Khanka Lake Basin (Kachur et al. 2001). The extent of possible expansion of agricultural lands for reclamation was estimated at 2 million ha in Amurskaya Oblast and 3 million ha in Khabarovskii Krai. However, development of these lands has not begun, owing to the 1990s economic crisis.

11.3.2 Environmental Consequences of Agricultural Activity

Drastic alterations in large parts of the plain and river valley landscapes may be considered the principal result of agricultural development in the Amur Basin during the twentieth century. In the Russian territory, 2.4 million ha of wetlands have been converted to arable land, hay fields, and pastures in the upper reaches of the Zeya River, Zeya-Bureya, Middle Amur Plain, and Khanka Lake lowlands. Additionally, at least 3 million ha of forest (predominantly on plains and along rivers) were also converted to agricultural land (Simonov and Dahmer 2008). In the Chinese part of the basin, meadows and wetlands of the Nongjiang-Sungari lowland have lost more than 25 and 8.5 % of their areas over 1980–2000. On the Sangjiang Plain, modifications were even more extensive. Wetland area was reduced by 52.5 %, while that of cultivated lands increased by 45 % over 1950–2000 (Liu et al. 2004; Wang et al. 2005; Wang et al. 2006).

A transformation of any type of land into agricultural ones degrades and depletes flora and fauna. Within the Zeya-Bureya and Khanka Lake plains of the Russian territory, transformation of wetlands into agricultural lands substantially reduced the number and diversity of resident birds including rare species, and worsened conditions for migration of birds of passage (Simonov and Dahmer 2008). On the Khanka Lake plain within the Khanka State Nature Reserve, 333 species of birds were identified. The number of birds of passage registered on the plain in spring can reach 100,000–130,000. However, this is much smaller than the number of migrating birds registered in the 1950–1960s (Kachur et al. 2001). There is an analogous situation on the Sangjiang Plain. Owing to landscape modification and decrease of habitat, the number of many rare and highly-valued species of waterfowl (e.g., red-crowned crane, Great Swan, and Oriental White Stork) has greatly decreased there (Liu et al. 2004; Wang et al. 2006).

Significant damage to biodiversity is also caused by the destruction of meadows, shrub vegetation, and forest cover. In the Russian territory, spring burning largely associated with farming not only eliminates small animals and birds, but frequently initiates large-scale forest fires, with widespread negative ecological consequences. Traditional problems related to agricultural exploitation of lands are soil fertility reduction and development of erosion. These problems were extensive on both sides of the national boundary in the Amur Basin as early as the first half of the twentieth century, and were related to insufficient application of fertilizer, plowing of slopes, and deficiency of crop rotation in response to local environmental conditions. With the beginning of widespread land conversion and development of drainage and irrigation, which modified the hydrologic regime and chemical composition of groundwater, these problems were exacerbated. In the 1950s, the problem of soil erosion became pressing in Jilin Province, because of forest overcutting and plowing of slopes in hilly and mountainous regions. The area of arable land affected by erosion was estimated at 1.3 million ha. In the same period, 17.1 million ha were damaged by erosion in Heilongjiang Province (U et al. 1963). Of this figure, 81 % was in forest and forest-steppe areas, and 19 % (3.2 million ha) on the plains. In 2010, the area subjected to soil erosion in that province was estimated at 13.8 million ha (Heilongjiang Statistical Yearbook 2011).

The situation of soil erosion in the Russian territory is characterized by the following data. In Amurskaya Oblast, soil erosion was noted across 146,800 ha, including 141,100 ha of 8.2 % arable land (Chub et al. 2003). In 2010, 278,000 ha of 24.5 % farmland were exposed to water and wind erosion in Primorskii Krai (Primorsky Krai Office 2010, 2011). In the Zabaikalskii Krai area, lands of agricultural enterprises subjected to erosion in 2008–2009 reached 5,000 ha of which 29 % is farmland, while annual losses of humus in arable lands were estimated at 0.8–6.3 t/ha (Zabaikalsky Krai office 2008–2009, 2011).

The problem of soil erosion is intimately connected with that of soil fertility maintenance. Studies in northeast China show that in soils reclaimed as cultivated lands from wetlands and meadows, soil nutrient content strongly decreases over a 5-year period (Wang et al. 2006). As a result, soil productivity drops significantly. This facilitates soil erosion and requires application of an increasing quantity of fertilizers for maintaining adequate fertility.

In the Chinese part of the Amur Basin, a campaign for broadening fertilizer application was launched in the 1950s, and near the end of the decade, fertilizers were introduced on 50–70 % of all sown areas in Heilongjiang and Jilin provinces (U et al. 1963). Soon after, in the 1960s, mass chemicalization of crop farming began in the Russian territory. The quantity of mineral and organic fertilizers applied per ha of cultivated land increased there between 1960 and 1980, from 35 to 135 kg and 1.5 to 3.5 t, respectively (Karakin and Zarkhina 1990). However, fertilizer application in the Russian territory dropped significantly from the beginning of the 1990s and in the 2000s; 10–50 kg/ha of mineral fertilizers and 0.2–0.3 t/ha of organic ones were used, depending on the administrative territory. Meanwhile, in the Chinese part of the Amur Basin, there was growth in fertilizer use (Fig. 11.6). The volume of applied fertilizers in Heilongjiang Province has almost doubled in just the past

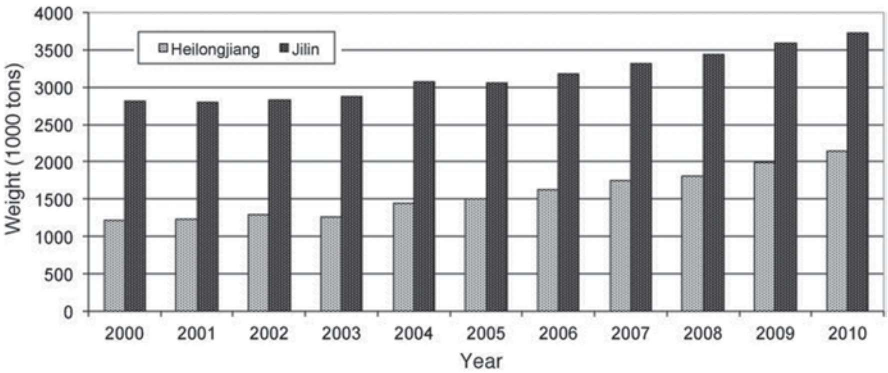


Fig. 11.6 Chemical fertilizer consumption. (1000 t, converting gross weight into weight containing active ingredient) (Heilongjiang Statistical Yearbook 2006, 2011; Jilin Statistical Yearbook 2006, 2011)

decade, reaching 188 kg/ha in 2010. In Jilin Province, this figure was 828 kg/ha (Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011). This mass use of fertilizers has a positive effect on agricultural production but is one of the greatest sources of water and soil pollution.

In the Russian territory, a problem of groundwater pollution and soil contamination associated with abuse of fertilizers, pesticides and herbicides was related to paddy cultivation. From 1981 to 1985, cultivated lands of the Khanka Lake plain received 104,000 t of nitrogenous, 55,000 t of phosphorous, and 43,000 t of potassium fertilizers. Of these quantities, it was calculated that 8000 t of nitrogenous, 420 t of phosphorous and about 5 t of potassium fertilizers entered lake waters (Kachur et al. 2001). Maximum pollution of these waters by biogenic substances was observed during 1986–1989. In the subsequent 10 years, there was a tendency toward pollution decrease, owing to a reduction of paddy plantations and natural growth in lake waters (Molokoedova 2002). This pollution had a major impact on the state of vegetation, fish populations, hydrobionts, and waterfowl inhabiting the water, as well as on the quality of cultivated agricultural products containing elevated concentrations of harmful substances. In other agricultural zones of the Russian part, pollution of soils and water bodies by fertilizers and toxic chemicals was not as extensive, but it greatly contributed to establishing an adverse ecological situation. In Amurskaya Oblast, there was excessive use of fertilizers for planting vegetables, potatoes, and perennial grasses. At times, doses of nitrogenous fertilizers exceeded 500 kg/ha. As a result, 7%–32% of plant products in the oblast were polluted by nitrates and nitrites, in amounts exceeding the maximum concentration level on several occasions (Chub et al. 2003).

In the Chinese territory, application of large amounts of mineral fertilizer is an important factor in nutrient pollution of surface waters. Overall, agriculture in this region is the largest water consumer. For example, it used 31.6 billion m^3 in 2010. This was 75% of all water in 2010 in Heilongjiang Province, and 64% (of

11.1 billion m^3) in Jilin Province. Nonindustrial waste waters in those provinces contained 38,000 and 26,800 t of ammonium nitrogen, or 88 and 90 % of total inflow of this substance to surface waters, respectively (China Statistical Yearbook 2011). Unfortunately, statistical data do not permit estimation of the contribution of agriculture alone to ammonium nitrogen pollution of waters, but one can assume that it is large. Additionally, crop farming is a source of other chemical pollutants in the water environment (e.g., pesticides and herbicides).

Agricultural development of the Amur Basin in the twentieth century had an asymmetric character (Baklanov and Ganzei 2004). This was primarily manifested by more intense and widespread reclamation and agricultural use of lands in the Chinese part of the basin. Current agricultural development there is greater than that of its Russian counterpart by a factor of 13. This caused more extensive and drastic transformation of the natural landscape in the Chinese portion, as well as more severe environmental problems such as deterioration of biodiversity, degradation and erosion of soils, and surface water contamination.

Moreover, from 1990 to the present, agricultural use of basin lands has been characterized by opposite tendencies. In the Chinese territory, cultivated lands continue to expand, while shrinking on the Russian side. Here, we point out that the economic downturn in Russian agriculture diminished the anthropogenic impact of this activity. That is, conversion of natural landscapes into agricultural lands nearly halted, pollutant input to soils and water bodies decreased, and it became possible to restore vegetation on unused agricultural lands. Improvement of water quality in Khanka Lake in the second half of the 1990s serves as a positive example. Nevertheless, modern trends in the dynamics of agricultural lands on both sides of the national boundary in the basin cause concern, because they indicate potential growth of environmental problems related to crop farming development. In the past 20 years, there has been expansion of agricultural output in the Russian territory, especially of cereals, soybeans, slaughter cattle and birds (Fig. 11.7), simultaneous with reduction of sown areas. During the economic downturn, most unsuitable, reclaimed and capital-intensive lands were removed from use. As a result, agricultural production concentrated within the old cultivated, densely-populated lands of the southern demographic zone of the Russian part of the basin. Many of these lands were put to use as early as the end of the nineteenth century. The application of fertilizers in recent decades remained slight, and there was no fundamental improvement in arable farming technology. This creates conditions for overharvesting and degradation of agricultural lands in the Russian part.

Analysis of statistical data from the Chinese part suggests that the majority of lands in Heilongjiang and Jilin provinces initially best suited to agricultural use and within the southern zone of active settlement and economic development were involved in farming as early as the first half of the twentieth century. In the ensuing years, growth of agricultural production was mainly realized by reclamation of unsuitable lands such as slopes, wetlands, cleared spaces and others, and intensive use of early developed territories. During the second half of the twentieth century and the last decade, the area of cultivated lands in both provinces steadily grew and the share of old cultivated farming zones remained high. This trend suggests a high

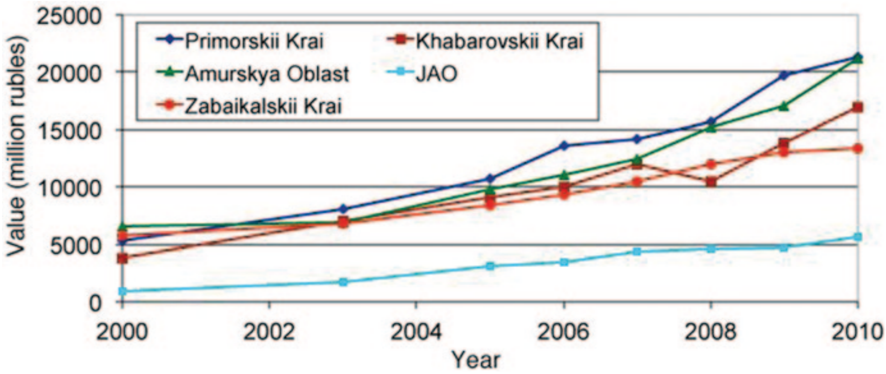


Fig. 11.7 Value of agricultural production in the south of the Russian Far East. (Some Agricultural Statistics of Zabaikalskii Krai 2011; Regions of Russia 2008; Far Eastern Region and Amurskaya Oblast in 2009, 2010; Far Eastern Federal Region in 2010, 2011b)

probability of further aggravation of many environmental problems related to transformation of the natural environment, under the influence of high-intensity farming.

11.4 Development of Forest Industry in the Amur River Basin and Its Environmental Consequences

According to data from satellite image interpretation, the area of forestland in 2000–2001 was 1.1276 million km^2, or more than half the Amur Basin (Ganzei et al. 2007). More than 30% of this area was mixed and coniferous forest, predominantly in the Russian territory. The majority of burned and cut areas and sparse forests were also in that territory. Deciduous forests, representing about 15% of all forestland, were mainly in the Chinese part of the basin. The most important factors of transformation of forest ecosystems in the basin are industrial harvesting and forest fires. The main environmental problems directly caused by timber harvesting are degradation and depletion of forest vegetation and animal life as well as deterioration of biodiversity. Further, given the significant environment-forming function of forests, their changes also provoke environmental problems of water, soil, and atmosphere.

11.4.1 Historical Overview of the Development of Forest Industry

Upon investigating the role of industrial harvesting in the development of environmental problems, it is necessary to consider three fundamental aspects: volumes and areas of harvesting, its methods, and its spatial distribution. Table 11.5 presents information on forested area in the Russian territory during the twentieth century,

Table 11.5 Estimation of forested lands in the south of the Russian Far East

Year of data	Forested Area,1000 km^2	Territory	Author, year of publication
1923	582.5	Far Eastern Oblast (Amurskaya and Primorskaya Guberniya)	Ivashkevich 1924
1925	541.1		Krokos 1926
1931	760	Far Eastern Krai	Seliber 1933
1932	586		Prokopenko et al. 1932
1963	753	Southern part of the Russian Far East	Problems of development. 1984
1978	756.8		
1998	894.2		Regions of Russia, 2008
2003	865.2		Regions of Russia, 2009
2008	902.1		

from various literary and statistical sources. There is substantial information on forests for the early 1920s. During this period, Soviet authority was established and a new economic policy was implemented, including enforced development of the timber industry. Nevertheless, data on forest areas were mostly hypothetical, because only about 15 % of their area was explored. As a result, differences in estimations of forested lands during the 1920–1930s fluctuated from 40,000 to 220,000 km^2.

Far East forests were fully inspected only in 1957, attributable to the use of aerial surveys. This is why, in the opinion of some scientists, there are no reliable data on forest area until the beginning of the 1960s. At that time, the first state forest accounting was done. Later results of these accountings, repeated every five years, were mainly used for tracking of forest land changes. Data from such inventories show that in the southern administrative units of the Far East, forested area generally increased beginning in 1963 (Table 11.5). We assumed that forest data in the first half of the twentieth century were mostly underestimates.

Forest data for Northeast China or Manchuria in the same half-century reveal two main trends. These were a decrease of forestland by the end of the 1930s and from the mid 1950s to the 1980s, and an increase from the 1930s to 1950s and in the 2000s (Table 11.6). Overall, these correspond to the tendencies of forest cover in China, but 1940 as a turning point is questionable. Most likely, the change from the 1930–1940s was largely caused by changes in methods and quality of forest area estimation. According to some sources, forests in Northeast China notably decreased during 1900–1948 and 1977–1980s (Yamane 2007).

Calculations based on data from land use and land cover maps show that from 1930 to 2000, forestland decreased across the entire Amur Basin, including its Russian and Chinese portions (Table 11.7). We believe that this negative trend is more representative of reality. This is because in the twentieth century, forest ecosystems in the basin were heavily exploited as a key resource base of the timber industry in the Russian Far East and Northeast China.

It is very difficult to estimate the scale of forest use in the basin during the first decades of the twentieth century, because available information is fragmentary and often contradictory. For example, by different estimates, yearly wood consumption

Table 11.6 Estimation of forested lands in Northeast China

Year of data	Forested area, $\times 10^3$ km^2	Territory	Author, year of publication
Beginning of the 1920s	380–390	North Manchuria	Northern Manchuria 1927
1930	274.7	Heilongjiang and Jilin Provinces	Surin 1930
1936	220	Manchuokuo	Japan-Manchuokuo Year Book 1938
1940	315	Manchuria	Sun 1973
1956	339	Heilongjiang and Jilin Provinces, part of the Inner Mongolia	Natural Resources and Questions of Economic Development of Northeast China 1975
1973	327.6	Heilongjiang and Jilin Provinces	Richardson 1990
1981	213.7		
2003	272.5		Statistical Yearbooks of Heilongjiang and Jilin 2004, 2011
2010	288.1		

Table 11.7 Changes of forested lands in the Amur River Basin from cartographic estimation. (Ganzei et al. 2007, 2010)

Territory	Area of forested lands, $\times 10^3$ km^2		
	1930–1940	2000–2001	Changes
Amur River Basin	1056.8	945.8	−111.2
Russian part of the Basin	668.1	563.3	−104.8
Chinese part of the Basin	373.5	363.0	−10.5

in North Manchuria in the early 1920s was 1.5–4 million m^3 (Surin 1930; Report on progress in Manchuria 1929). The smaller figure largely reflects wood volume produced by enterprises of the timber complex. The larger value considers both local consumption of timber by fire and forest cutting for conversion to agricultural land. In the early 1920s, wood consumption in the south of the Russian Far East was about 5.5 million m^3 (Sheingauz 1973).

Data for the Russian part of the basin in the late 1930s suggest a substantial increase in forest extraction, up to 10 million m^3 (Shulyatyev 1974), which was related to active economic development as part of the industrialization program and construction expansion. According to Japanese statistics, volumes of forest extraction in North Manchuria reached 2–2.5 million m^3 in the second half of the 1930s (The Manchuokuo Year Book 1942). This likely fails to account for forest use by local populations. Information on the economic situation in Manchuria in the 1940s is fragmentary and incomplete. However, it is assumed that intensive forest cutting in the Chinese part of the Amur Basin persisted. Analyzing the history of reduction of China's forests, Zhang (2000) concluded that the most significant variations were during wars and periods of political instability. It is possible to apply this thesis to Manchuria for the second half of the 1940s. This is because in the period from the end of World War II and Japan's departure from the region to the founding of the

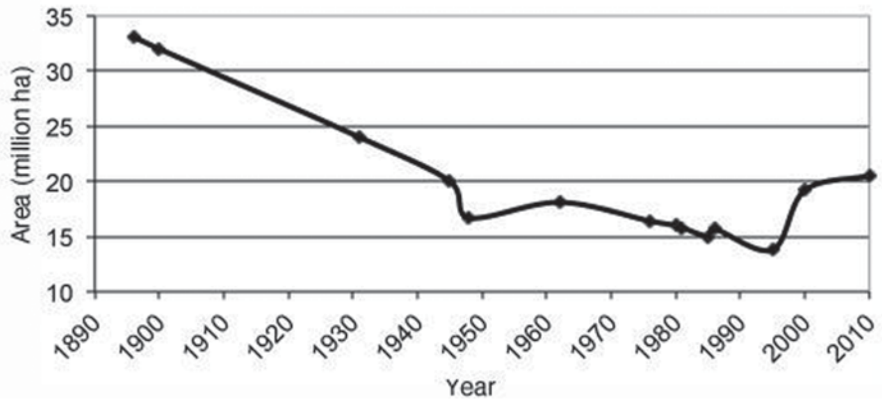


Fig. 11.8 Changes of forest area in Heilongjiang Province. (Zhang 2000; Ganzei 2004; Heilongjiang Statistical Yearbook 2011)

PRC in 1949, Manchuria passed through multiple changes of authority and military struggles. Under such conditions, forest use was probably uncontrolled and oriented mostly toward internal consumption. Data on use of forest resources in Northeast China during the first half of the twentieth century indicated a significant reduction of forested area. In Heilongjiang Province, this decreased nearly 50 % from 1900 to 1948 (Fig. 11.8).

From the founding of the PRC until now, Heilongjiang and Jilin provinces and Inner Mongolia Autonomous Region were the principal suppliers and largest consumers of wood in China. According to 1950s data, about 44 % of forest area and 40 % of total wood stock in the country were in this area. Heilongjiang Province was the leader in timber industry production in Northeast China during the second half of the twentieth century. Logging volume there rapidly expanded in the 1950s, from 3.5–10.7 million m^3. At the beginning of the 1970s, annual output of wood products reached 11–12 million m^3 according to data from one source, and 15–16 million m^3 from another (Yamane 2007). In the 1990s, timber harvesting decreased and, at the end of the decade, annual logging volume was between 6 and 10 million m^3 from various estimates (Yamane 2007).

In the second half of the twentieth century, forest use in the Chinese part of the Amur Basin greatly increased. Logging volumes in Heilongjiang Province alone exceeded by two to four times the timber production in all Manchuria in 1939. Acceleration of timber harvesting in Northeast China coincided with implementation of various governmental programs of national development, such as the Great Leap Forward, Cultural Revolution, economic reforms, and policy of external openness in 1978. In the Russian part of the basin in the 1930s, growing internal demand for lumber, firewood, and building materials increased logging volumes, to 31.8 million m^3 in 1940. Around 20.6 million m^3 of that was harvested in the southern Far East (Sheingauz 1973). During 1940–1947, wood production declined because of World War II. Growth of logging volumes began in the 1950s and continued until

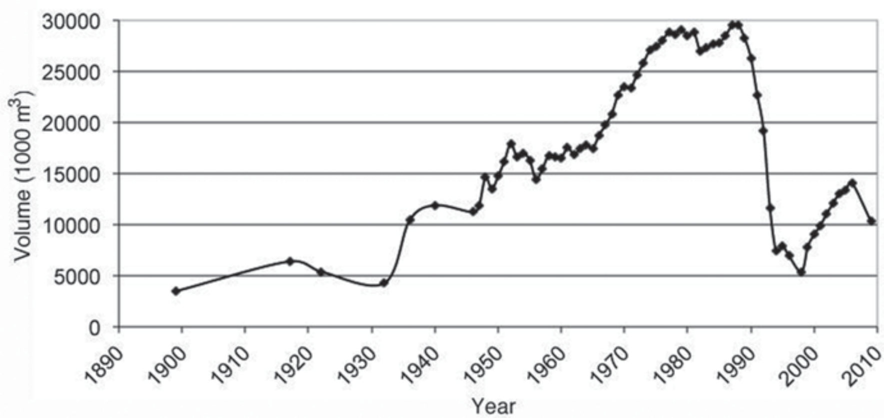


Fig. 11.9 Timber logging in the south of the Russian Far East. (Data derived from various literary and statistical sources)

the mid 1980s. The largest output of forest products in the southern Far East exceeded 25 million m^3 (Fig. 11.9). A decrease of production that began in the second half of the 1980s was accelerated by onset of the economic crisis in the 1990s. Logging volumes began recovering in 1998. During nearly all the postwar period, the crucial Far East producers of timber were the Khabarovskii and Primorksii krais and Amurskaya Oblast. From the mid 1950s, these three administrative entities of the Amur Basin made up more than 70 % of regional timber output.

In Chitinskaya Oblast, which forms the major portion of the Transbaikalia territory of the Amur, active commercial exploitation of the forest raw material base commenced in the 1950s. A sector along the main Trans-Siberian railway (width 150–200 km) was used as the basic harvest area. Maximum forest extraction was in the 1980s, when 5.6–5.7 million m^3 of timber was produced annually in the oblast. A decline in forest product output began in 1991. There was growth after 1998, as was the case in the southern RFE (Transbaikalia 2000).

A characteristic of the timber complex in the Russian part of the basin is its significant orientation toward export. In the 1920–1930s, between 10 and 30 % of all harvested timber in the southern Far East was exported. The proportion of forest export varied within the same limits over 1962–1990. From the beginning of economic reforms and crisis in Russia, the portion of export in timber production increased significantly, attaining 40 % in 1995 (Sheingauz 2006) and 87 % in 2005 (Antonova 2007). During the entire export history of Far East forest, round timber was a major export. In 1920–1937, its share of forest export varied interannually between 80 and 100 %; after 1960, it did not drop below 90 %.

Generally, on both sides of the national boundary in the basin, the main trend of forest use remained constant from the mid 1950s to early 1990s, being a continuous increase of forest harvesting. Tendencies of such harvesting in the Russian and Chinese parts of the basin diverged in 1992. In the Russian territory there was a significant reduction, to a minimum of 5.4 million m^3 in the late 1990s (Fig. 11.9).

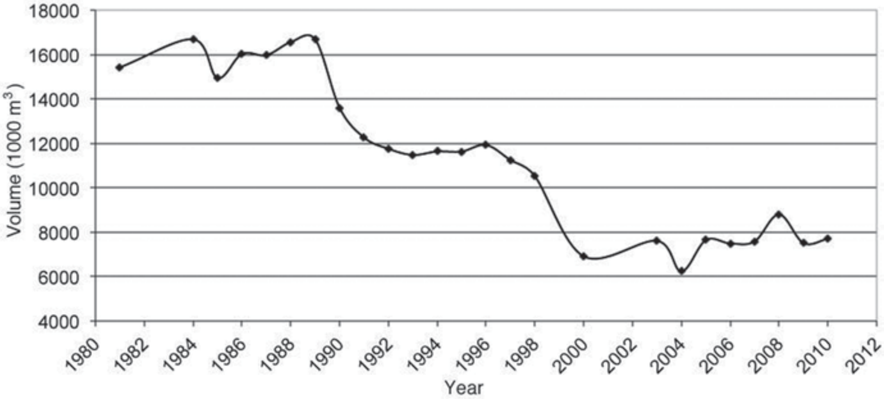


Fig. 11.10 Log production in Heilongjiang province. (Richardson 1990; Yamane 2007; Heilongjiang Statistical Yearbook 2006, 2011)

Afterward, there was an increase in harvesting volume, to 16.1 million m^3 in 2007. This was followed by another decline in wood production, attributable to the Russian Federation government increase of customs duties on imports of unprocessed timber. In the Chinese territory, a gradual reduction of harvesting volumes began in the 1980s and continued in the 1990s. In the 2000s, logging dynamics were unstable, and wood production varied within a relatively narrow range (Fig. 11.10).

11.4.2 Environmental Consequences of the development of Forest Industry

The common trait of forest exploitation in both the Chinese and Russian basin territories is its exhaustive character. Forest use remained unsustainable, independent of dominant direction of consumption, existence of external influence, or national political regime. However, the reasons and mechanisms of such unsustainable and exhaustive use varied. In the Russian territory, basic causes of forest damage are extraction methods and under-exploitation of felled forest. The direct effect of timber withdrawal is not catastrophic; with controlled harvesting, processes similar to tree dieback ensue. If remaining trees or the understory are preserved, ecological functions weaken temporarily but are not interrupted. More harmful components for ecosystems are haulage roads, conversion points and loading ramps, which represent 20–32 % of harvesting compartments. These are absolutely extraneous to forest ecosystem technologic formations, among which the biocenosis are completely destroyed. The timber harvesting components are especially destructive on steep and erosion-vulnerable slopes. When using such technologies, each cubic meter of produced timber is associated with processing of one cubic meter of ground. Thus, many erosion sources emerge and the hydrologic regime of mountain slopes is disturbed. This causes further forest mortality and transformation of slope ecosystems (Sheingauz 2005b).

The under-exploitation of woodcutting areas in the Russian Far East was caused by selective cutting and conditional clear felling, in which only the higher-quality part of wood is removed from timber stands. About 30–50 % of initial stocks of raw materials, with lesser value but suitable for industrial use, are left onsite (Sheingauz 2005a). Harvesting of each 3 m^3 of wood is accompanied by loss of 1–1.5 m^3. In later stages, losses reach 1 m^3 for every 2 m^3 of used or processed wood (Batalov 2008). Negative ecological consequences of such destructive harvesting results in prompt expansion of logged areas, change of high-value coniferous forest to a less valuable deciduous one, fire danger increase, degradation of forest age structure, and reduction of total wood stock, among others. On one hand, such an approach to timber harvesting and use of raw wood was determined by objective factors. These are impossibility of selling or processing low-grade wood for lack of processing facilities in the region, small external demand for that wood, and unprofitability of transportation of such woody goods to other regions. On the other hand, the fact that facilities required for processing of low-grade wood were not established for nearly 100 years of industrial harvesting is a reflection of government policy regarding exploitation of Far East natural resources.

Given the aforementioned problems, development of forest product export (mainly unprocessed wood) from the Far East has promoted the use of irrational selective cutting in all stages of regional development. This contributed to degradation of forest health in the southern Far East and persistence of problems in the forestry industry. Many researchers have studied Far East timber industry development and its influence on forest health, noting that increases in round wood export amplifies certain forest use problems and negative consequences of forest exploitation (Krokos 1926; Surin 1930; Sheingauz 1973, 1997, 2004, 2005a, 2006).

According to literature sources, timber harvesting methods in North Manchuria similar to those in the Far East were typical during Russian influence, through the end of the 1920s (Surin 1930). After formation of the PRC, Northeast China became one of the leading suppliers of forest products, and expansion of wood production there was initiated. Both selective and clear felling were used (Yamane 2007). In contrast to the Russian territory, timber harvesting in China was associated with thrifty use of timber, including branch wood down to 3-cm diameter. Even twigs and hardwood foliage were collected for goat fodder (Richardson 1990). Overall in the second half of the twentieth century, felling of native forests was conducted across vast territories, without any special attention to forest restoration. For example, from the 1950s through 1980s, about 1.5 million ha of forests were cut in the Changbai Mountains. As a result, no accessible mature natural forests remained by the end of the twentieth century. Over the same period, about 0.3 billion m^3 of felled timber, or 1/7 of total Chinese output of rough timber, was harvested in the Little Khingan Mountains. It is not surprising that in some areas of these mountains, the growing stock of forest declined by a factor of two, and the proportion of coniferous forests decreased by 15 % (Zhang 2000). The distinctive characteristic of forest exploitation in the Chinese territory was conversion of logged-off forestland

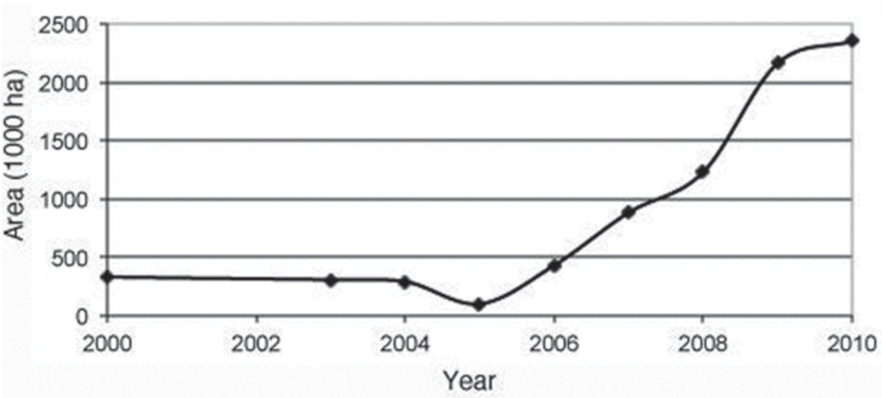


Fig. 11.11 Area of afforestation in Heilongjiang Province. (Heilongjiang Statistical Yearbook 2006, 2011)

to agricultural use. Such agricultural land expansion was common in the first half of the twentieth century (Surin 1930) and subsequent years. Pressure on forest resources and transformation of forestlands substantially reduced the forested area of Northeast China in the 1960–1980s (Table 11.6). This caused numerous environmental problems related to intensification of soil erosion, disturbance of hydrologic regime, increased flood risk, depletion of biodiversity, and others.

There were major changes in national environmental policy regarding forests and their exploitation, turning from their destruction to restoration in the Chinese territory. These began in the 1990s with realization of the Natural Forest Protection Project (Yamane 2007). In 1998, the PRC government implemented a law restricting logging of natural forests in Northeast China. As a result, total volume of cut timber decreased (Fig. 11.10) and programs of forest restoration began. In the last decade, the area of afforestation in Heilongjiang Province increased sevenfold (Fig. 11.11). In 2010, the area of artificial forests in the province reached 12 % that of all forests, and in Jilin Province this figure was 20 % (China statistical yearbook on environment 2011). Mainly because of the active policy of afforestation, forestland increased 37–45 % and 23.5–43.6 % in Heilongjiang and Jilin, respectively, from 1980 to 2010 (He et al. 2008; Heilongjiang Statistical Yearbook 2011; Jilin Statistical Yearbook 2011).

In the Russian Far East, the aforementioned methods of wood harvesting and approaches to forest exploitation remain unchanged to the present. In 2006, the Russian government passed a resolution for a gradual rise of export taxes on rough timber, with the goal of wood processing development. It is expected that this initiative will have positive economic and ecological effects. Owing to the economic crisis of 2008–2009, however, imposition of these taxes was halted and has not yet been executed. A short-range effect took the form of logging volume decrease in the Russian part of the Amur Basin. However, in 2010 the output of rough timber in Primorskii, Khabarovskii, and Zabaikalskii krais increased again (Fig. 11.9).

Despite strong growth of timber cutting in the southern Far East and Zabaikalsky Krai during the second half of the twentieth century, the area of forests in the Russian part of the basin changed little (Table 11.5). Nevertheless, forest health took a turn for the worse. In the early 2000s, the extent of forest transformation in the southern Far East was estimated around 40 % (Sheingauz 2008).

11.4.3 Forest Fires in Amur River Basin

Forest fires are considered another significant factor of forest transformation in the Amur Basin. According to land use maps, the area of forests destroyed by fires in the Russian basin was 17,200 km^2 in the 1930–1940s, increasing to 26,400 km^2 by 2001. In the Chinese territory, the area of burnt forest was not identified during earlier periods, but in the early twenty-first century, it was estimated at 509 km^2 using satellite image analysis. Generally, the Russian Far East is characterized by high fire danger. During extreme weather conditions (drought), forest fires become catastrophic approximately once every 10 years (Sheingauz 2008). The causes of forest fires are both anthropogenic and natural. Most small- and medium-scale fires originate in the most populated parts of forests near settlements along roads and rivers. Many fires are associated with locations of active forest use, such as felling, gathering of wild edible plants, and recreation. Additionally, fires are more frequent along the Sea of Japan coast and major traffic arteries, such as the Trans-Siberian Railroad and Baikal-Amur Mainline (Yamane 2010).

The annual number and areas of fires vary greatly by administrative territory. Over 2000–2010, Zabaikalskii Krai had a record number of fires in the Russian part of the Amur Basin, nearly 13,000. The year 2003 had the largest overall number of fires in all administrative formations of the basin (more than 5,500 events). The same year had the most forested area subjected to fires, about 1.4 million ha or approximately 1 % of all forested lands (Fig. 11.12). Considerable forest areas were burnt out during 2008–2009. Zabaikalskii Krai was damaged by fire to maximum extent in 2003, and Khabarovskii Krai and Amurskaya Oblast in 2008 and 2009, respectively. From 2003 to 2010, more than 69 million m^3 of forest standing volume was burned away or damaged (Table 11.8). This figure is the volume (72 million m^3) of timber harvested in the same territories from 2004 to 2010. The most damage was caused by forest fires in Zabaikalskii and Khabarovskii krais and Amurskaya Oblast.

In the struggle against large-scale forest fires, the fire prevention system has tremendous importance. In the Russian territory, protection against forest fires was the responsibility of the forest service, and until 2005 it was a specialized, well-trained organization. However, in the early 1990s, activity related to organization of fire protection in the territory practically ceased, owing to contraction of financing. Since 2007, all functions concerning forest conservation and protection were transferred from the central administrative office of the country to the level of subjects of the Russian Federation, which reduced the number of employees and continued the

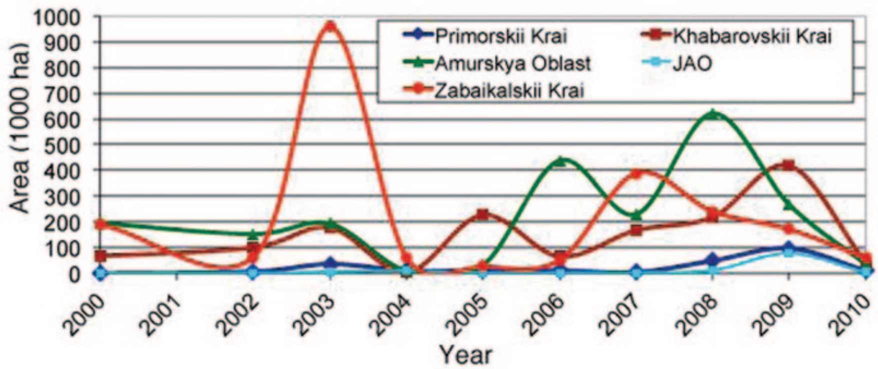


Fig. 11.12 Area burnt by forest fires in the south of the Russian Far East and Transbaikalia. (Regions of Russia 2008, 2009; Forest Complex of Primorskii Krai: Statistical Survey with Analytical Note 2010, 2011; Statistical Yearbook of Zabaikalskii Krai 2011)

Table 11.8 Burned and damaged forest standing volume $\times 10^3 m^3$. (Source: Forest Complex of Krai in Current Economical Conditions 2011; Statistical Yearbook of Zabaikalskii Krai 2011)

	2003	2004	2005	2006	2007	2008	2009	2010	Total in 2003–2010
Primorskii Krai	2559.2	253.4	57.6	159.8	20.9	1172.6	223.9	116.3	4563.7
Khabarovskii Krai	7780.9	29.9	3072.3	1113.2	2434.6	3921.	3518	337.2	22207.1
Amurskaya Oblast	1087.4	88.8	226.3	1511.2	1693.8	4039.2	1685.9	120.3	10452.9
EAO	39.3	37.3	10.3	145.9	8.7	31.7	611.3	14.2	898.7
Zabaikalskii krai	18974.7	1849.4	564.8	421.1	4354.5	3213.4	1147.1	597.1	31122.1
Total	30441.5	2258.8	3931.3	3351.2	8512.5	12377.9	7186.2	1185.1	69244.5

shrinking of subsidization. Current forest fire prevention services of the southern Far East are capable of monitoring situations with moderate-frequency forest fire occurrence, but have inadequate manpower and resources for suppression of large-scale catastrophic fires. The latter type of fire usually proceeds spontaneously and ends with abundant rainfall (Sheingauz 2008).

In the Chinese territory, forest fires are also a serious problem, dramatically worsening the condition of wooded lands. From 1950 to 1990, more than 620,000 fires were recorded in the territory, resulting in about 36 million ha of burnt-out forests (Zhong et al. 2003). Heilongjiang Province and Inner Mongolia Autonomous Region are among five leading provinces in forest areas subject to fires. Every year, their share of all burnt-out forests in China is about 50 % (Zhong et al. 2003). Through the mid 1960s, more than one million ha of forests in Heilongjiang

Province were affected by fire each year. In spring 1955, damage by large-scale fires in the Great and Little Khingan Mountains reached 2.5 million m^3 of timber. In 1987, there was a catastrophic forest fire in the former mountains. The burnt area and affected forest reached 1.33 million ha and 0.89 million ha, respectively, and burnt stock volumes were about 39.6 million m^3 (Zhong et al. 2003).

The number of fires decreased noticeably only in the 1990s (Yamane 2010). Strengthening of the monitoring system for forest fire safety was a likely cause, because in 1988, the "Forest Fire Protection Rules" clearly spread responsibilities for forest fire protection among authorities at various levels. In the same year, the forest police was established as the main force in wildfire suppression (Zhong et al. 2003). As in the Russian territory at the same time, annual forest fire frequency in the Chinese part of the Amur Basin varied greatly and, in many respects, depended on weather conditions. For example, in 2003, the total area of forest fires in Heilongjiang Province was about 800,000 ha, with 287,000 ha completely burnt. In the same year in Inner Mongolia, 122,000 ha of forests were burnt away (China Statistical Yearbook 2004). As indicated earlier, the Russian part of the basin had an extremely high frequency of forest fires in 2003 (Table 11.8). In 2010, areas of forest fires in Heilongjiang Province and Inner Mongolia were much smaller, 13,800 and 9,000 ha, respectively (China Statistical Yearbook 2011).

Consequently, prevention and suppression of large-scale fires are the most important tasks in supporting the environmental stability of basin-wide forest ecosystems. As noted by specialists, forests in the southern Far East of Russia have strong natural regeneration and, therefore, investments in fire prevention measures are much more effective for forest restoration than forest replanting (Sheingauz 2008). In the Chinese territory, improvement of the fire suppression system is particularly topical for preserved native forests, because they are more subject to destruction from fires than artificial forest plantations. For instance, in Heilongjiang Province, forest areas destroyed by fire in 2003 and 2010 were completely natural forest (China Statistical Yearbook 2004; China Statistical Yearbook on Environment 2011).

Generally, over the last 150 years, forests in the Amur Basin have endured increasing anthropogenic impact, related to population growth and economic development. Intense logging activity and forest fires have generated a wide spectrum of environmental problems on both sides of the Russia-Chinese boundary, including: fragmentation of forest cover and degradation of species composition; depletion of diversity of forest ecosystems and reduction of wildlife habitats; irreversible changes of hydrologic regime of water courses; water quality impairment; increase of flood frequency; intensification of soil erosion and degradation; and reduction of biological productivity of spawning grounds. Forest ecosystems in the Chinese part of the basin have experienced greater transformation, with significant decrease of natural forest areas and increase of artificial forest plantations. In the Russian section, despite unsustainable forest management, there were no major changes to forestland area or total timber resources, and forest resources maintained the potential for development of the forest industry complex. However, further increase in logging without radical changes in felling methods and wood processing development may strongly deteriorate the ecological state of forest ecosystems. Activity focused on prevention and control of large-scale forest fires is of great importance for forest protection in both the Russian and Chinese sectors.

11.5 Conclusion

The natural environment of the Amur River basin significantly changed in the twentieth century, owing to active settlement and development of economic activity. Basin population increased 13-fold, from 5.25–67 million. The area of cultivated land rose by almost three fold, from 137,500–373,000 km^2, and that of forest decreased by 111,200 km^2. Overall, the areal reduction of natural lands and rapid increase of anthropogenic landscapes can be considered general tendencies of land use/cover change in the basin. Analysis of land-use dynamics in the basin suggests that economic development and land use in the Chinese part, with about 90 % of the total basin population, were more intense and destructive in the twentieth century than on the Russian side. These phenomena were responsible for deeper and more radical transformation of natural landscapes in the Chinese portion, as well as more severe environmental problems such as depletion of biodiversity, degradation and erosion of soil, surface water contamination, reduction of natural forest area, increased flood risk, and others. Many of these problems are also drastically increasing the risk of environmental deterioration in the Russian part of the basin. The natural environment in this part had less anthropogenic change than in the Chinese part during the twentieth century. However, there were various environmental problems in the Russian area, many of which were a consequence of unsustainable exploitation of natural resources plus inefficient, wasteful management. For improvement of the environmental situation in the Amur Basin territories, it is necessary to develop a common, coordinated system of Russian and Chinese policy for environmentally sustainable land use. There was significant scientific work in this direction during the Amur-Okhotsk Project. It is hoped that everyone interested in improvement of the ecological situation in the Amur Basin will continue to cooperate under the framework of the Amur-Okhotsk Consortium established in 2009, toward achievement of necessary and desired results.

References

Amurskaya Oblast's Regional Department of Federal State Statistics Service (2011) Municipal formations of Amurskaya Oblast. Amurstat, Blagoveschensk, p 278 (in Russian)

Amurskaya Oblast's Regional Department of Federal State Statistics Service (2010) Far Eastern region and Amurskaya Oblast in 2009. Statistical survey. Amurstat, Blagoveschensk, p 265 (in Russian)

Amurskaya Oblast's Regional Department of Federal State Statistics Service (2011) Amursky statistical yearbook. Amurstat, Blagoveschensk, p 592 (in Russian)

Amurskaya Oblast's Regional Department of Federal State Statistics Service (2011) Municipal formations of Amurskaya Oblast. Amurstat, Blagoveschensk, p 278 (in Russian)

Antonova NE (2007) Problems of interaction of the Russian Far East and North-East China forestries taking into account the consequences of the Russian Federation entry into WTO. In: Problems of sustainable nature management in the lower reaches of Tumen River: Proceedings of international conference FEB RAS, Vladivostok, pp 25–28 (in Russian)

Baklanov PYa, Ganzei SS (2004) Principal stages and tendencies of land use development in the Amur basin. Geogr Nat Resour 4:19–28 (in Russian)

Bank of Chosen (1920) Economic history of Manchuria compiled in commemoration of the decennial of the Bank of Chosen. Chosen, Seoul, p 303

Batalov VE (2008) Providing of conditions and state support for attracting investments into forest industry. Reports of participants of the third Far Eastern International Economic Forum. http://www.dvforum.ru/doklads/ks5_batalov.aspx. Accessed 10 Nov 2008 (in Russian)

Chub AB (2003) Geography of natural resources and nature use in Amurskaya Oblast. Publishing house Zeya, Blagoveschensk, p 216 (in Russian)

Darman Yu, Karakin V, Martynenko A, Williams L (2003) Conservation action plan for the Russian Far East Ecoregion Complex. Part 1. Biodiversity and socio-economic assessment. WWF, Vladivostok, p 176

Economic Bureau of Chinese Eastern Railway (1927) Northern Manchuria and Chinese Eastern Railway. Harbin, p 607 (in Russian)

Evreiskaya Avtonomnaya Oblast's Regional Department of Federal State Statistics Service (2011) Socioeconomic characteristics of Birobidzhan City and districts of Evreiskaya Avtonomnaya Oblast. Statistical survey. Evrstat, Birobidzhan, p 145 (in Russian)

Evreiskaya Avtonomnaya Oblast's Regional Department of Federal State Statistics Service (2011) Passport of Evreiskaya Avtonomnaya Oblast. Evrstat, Birobidzhan, p 89 (in Russian)

Federal State Statistics Service of Russian Federation (2009) Regions of Russia. Social-economic indicators in 2008: Statistical Survey. Rosstat, Moscow, p 990 (in Russian)

Frizendorf M (1929) Northern Manchuria. Knizhnoe delo, Khabarovsk, p 189 (in Russian)

Federal State Statistics Service of Russian Federation (2008) Regions of Russia: Social-economic indicators in 2007. Rosstat, Moscow, p 999 (in Russian)

Federal State Statistics Service (2009) Regions of Russia. Social-economic indicators in 2008: statistical survey. Rosstat, Moscow, p 990 (in Russian)

Ganzei SS (2004) Transboundary geo-systems in the south of the Russian Far East and Northeast China. Dalnauka, Vladivostok, p 231 (in Russian)

Ganzei SS, Mishina NV (2005) Land-use and Land-cover changes in the Amur River Basin (South of the Russian Far East and North-East China). In: Land-use and land-cover changes in the separate regions of the world. IGU—LUCC Atlas, vol 4, pp 49–62

Ganzei SS, Yermoshin VV, Mishina NV, Shiraiwa T (2007) Current land use in the Amur basin. Geogr Nat Resour 2:17–26 (in Russian)

Ganzei SS, Yermoshin VV, Mishina NV (2010) The dynamics of land use within the Amur basin in the twentieth century. Geogr Nat Resour 1:30–38 (in Russian)

Ganzey SS, Ermoshin VV, Mishina NV (2010) The landscape changes after 1930 using two kinds of land use maps. In: Shiraiwa T (ed) Report of Amur-Okhotsk project, vol 6, pp 251–262

Geniatulin RF (2000) Encyclopedia of Transbaikalia. Chita Region. V. 1: general survey. Siberian Branch of RAS, Chita Institute of natural resources, ecology and cryology. Nauka, Novosibirsk, p 302 (in Russian)

He F, Ge Q, Dai J, Rao Y (2008) Forest change of China in recent 300 years. J Geogr Sci 18(1):59–72

Heilongjiang Statistical Office (2004) Heilongjiang statistical yearbook. China Statistics Press, Beijing, p 540

Heilongjiang Statistical Office (2006) Heilongjiang statistical yearbook. China Statistics Press, Beijing, p 543

Heilongjiang Statistical Office (2011) Heilongjiang statistical yearbook. China Statistics Press, Beijing, p 693

Himiyama Y (1997) Land use in North-East China in the 1930s and after. IIASA Interim Report IR-97-011. http://www.iiasa.ac.at/Admin/PUB/Documents/IR-97-011.pdf. Accessed 15 June 2006
Inner Mongolia Statistical Office (2011) Inner Mongolia statistical yearbook. China Statistics Press, Beijing, p 799
Ivashkevich BA (1924) Economical factors of forestry in Primorye. Econ life Primorye 4(8):1–17 (in Russian)
Japan-Manchuokuo Office (1938) Japan-Manchuokuo Year Book. Tokyo, p 1304
Japan-Manchuokuo Office (1939) Japan-Manchuokuo Year Book. Tokyo, p 1202
Japanese Railways Office (1913) An official guide to Eastern Asia. Trans-continental connections between Europa and Asia. V. 1. Manchuria and Chosen, Tokyo, p 350
Jilin Statistical Office (2004) Jilin statistical yearbook. China Statistics Press, Beijing, p 550
Jilin Statistical Yearbook (2006) Jilin statistical yearbook. China Statistics Press, Beijing, p 619
Jilin Statistical Yearbook (2011) Jilin statistical yearbook. China Statistics Press, Beijing. p 649
Kachur AN (2001) Diagnostic analysis of the Lake Khanka Basin (Peoples republic of China and Russian Federation). UNEP/CRAES/PGI FEBRAS, Vladivostok, p 136
Karakin VP (2009) Problems of food security of the Russian Far East. In: Regional politics of Russia in modern social-economic conditions: geographical aspects. Proceedings of the 9th symposium of applied geography. Publishing House of Geographical Institute named by V. B. Sochava SB RAN, Irkutsk, pp 11–13 (in Russian)
Karakin VP, Sheingauz AS (2004) Land resources of the Amur river basin. Bull Far Eastern Branch RAS 4:23–37 (in Russian)
Karakin VP, Zarkhina ES (1990) Consequences of applying of traditional methods of the agriculture intensification. In: Ecological-and-economical aspects of new territories development. FEB RAS, Vladivostok, pp 137–146 (in Russian)
Khabarovskii Krai's Regional Department of Federal State Statistics Service (2011a) Environmental conditions of Khabarovskii Krai in 2010. Statistical survey. Khabarovskstat, Khabarovsk, p 62 (in Russian)
Khabarovskii Krai's Regional department of Federal State Statistics Service (2011b) Far Eastern Federal Region in 2010 (Statistical Survey). Khabarovskstat, Khabarovsk, p 167 (in Russian)
Krokos PI (1926) Perspectives of timber industry of the Far East. In: Productive forces of the Far East, vol 6. Industry, pp 3–19 (in Russian)
Liu H, Zhang S, Li Z, Lu X, Yang Q (2004) Impacts on wetlands of large-scale land use changes by agricultural development: the small Sanjiang plain, China. Ambio 33(6):306–310
Manchuokuo Office (1942) The Manchuokuo Year Book, Hsinking, p 971
Manchuria Railway Office (1929) Report on progress in Manchuria: 1907–1928. Dairen, p 238
Minakir PA, Mikheeva NN (1999) Russian Far East: an Economic Potential. Dalnauka, Vladivostok, p 594 (in Russian)
Mishina NV (2008) Role of forest trade relations between Russia, Japan and China in development and utilization of the Amur Basin's forest. In: Report of Amur-Okhotsk project 3:171–182
Mishina NV (2010) Foreign trade relations between Russia China and Japan as factor of Land use/cover changes in the Amur River Basin. Report of Amur-Okhotsk project 6:273–281
Molokoedova EA (2002) Ecological state of the Khanka lake. http://www.primpogoda.ru/articles/ecology/ekologicheskoe_sostoyanie_ozera_hanka/. Accessed 15 June 2011 (in Russian)
National Bureau of Statistics of China (2004) China statistical yearbook. China Statistics Press, Beijing. http://www.stats.gov.cn/english/statisticaldata/yearlydata/yb2004-e/indexeh.htm. Accessed 15 May 2012
National Bureau of Statistics of China (2011) China statistical yearbook. China Statistics Press, Beijing. http://www.stats.gov.cn/tjsj/ndsj/2011/indexeh.htm. Accessed 15 May 2012
National Bureau of Statistics, Ministry of Environmental Protection of China (2011) China statistical yearbook on environment. China Statistics Press, Beijing, p 320
Natural resources and questions of economic development of North-East China (Materials of Amur expedition of AS USSR and Heilongjiang expedition of CAS) (1975) Moscow, p 259 (in Russian)

Nersesov MN (1926) Economical outlines of the Far East. Center of printing management of the USSR Supreme Council of National Economy, Moscow-Leningrad. p 121 (in Russian)
Population of Zabaikalskii Krai. Web-site of Zabaikalskii Krai's Regional Department of Federal State Statistics Service. http://chita.gks.ru/digital/region1/default.aspx. Accessed 25 October 2011 (in Russian)
Primorskii Krai's Regional Department of Federal State Statistics Service (2010) Forest complex of Primorskii Krai: statistical survey with analytical note. Primkraistat, Vladivostok, p 36 (in Russian)
Primorskii Krai's Regional Department of Federal State Statistics Service (2011) Forest complex of Primorskii Krai: statistical survey with analytical note. Primkraistat, Vladivostok, p 33 (in Russian)
Primorskii Krai Statistical Office (2011) Yearbook of Primorskii Krai. Primkraistat, Vladivostok, p 319 (in Russian)
Primorskii Krai's Regional Department of Federal State Statistics Service (2011) Socioeconomic situation in municipal formations. Statistical survey. Primorskstat, Vladivostok, p 164 (in Russian)
Prokopenko G, Kizin I, Genischenko K (1932) Far Eastern Krai: political and economical survey. Dal'gis, Khabarovsk, p 96 (in Russian)
Richardson SD (1990) Forest and forestry in China: changing patterns of resource development. Island, Washington D.C., p 352
Second report on progress in Manchuria to 1930 (1931) South Manchuria Railway Company, Dairen, p 307
Seliber B (1933) Forest and forest industry of the USSR. Vol. 1. Forest of the USSR and their exploitation. Goslestekhizdat, Leningrad, p 428 (in Russian)
Sheingauz AS (1973) Development of forests of the Far East and their utilization from the middle of the 19th to the middle of the 20th century. In: Improvement of efficiency of the Far Eastern forests. Lesnaya promyishlenost, Moscow, pp 83–110 (in Russian)
Sheingauz AS (1997) Natural resource use of the Russian Far East and Northeast Asia. RIOTIP, Khabarovsk, p 224 (in Russian)
Sheingauz AS (2004) Overview of the forest sector in the Russian Far East: production, industry and the problem of the illegal logging. Forest trends publications and reports. http://www.forest-trends.org/publication_details.php?publicationID=115. Accessed 23 April 2006
Sheingauz AS (2005a) Forest sector of the Russian Far East analytical survey. FEB RAS, Vladivostok, p 160 (in Russian)
Sheingauz AS (2005b) Natural resource use of the Russian Far East and Northeast Asia: potential of integration and sustainable development. FEB RAS, Vladivostok, p 528 (in Russian)
Sheingauz AS (2006) Far Eastern forest export: pluses and minuses of long-term transboundary relations. In: Problems of sustainable use of the transboundary territories. Proceedings of the international conference. PGI FEB RAS, Vladivostok, pp 146–149 (in Russian)
Sheingauz AS (2008) Forest sector of the Russian Far East analytical survey, 2nd edn, revised and supplemented RIOTIP. Khabarovsk, p 192 (in Russian)
Shulyatyev DA (1974) Logging industry of the Far East: historic-economical study. Far Eastern Research Institute of Forest Industry, Khabarovsk, p 336 (in Russian)
Simonov EA, Dahmer TD (2008) Amur-Heilong river basin reader. WWF, Ecosystems Ltd, Hong Kong, p 426
Some agricultural statistics of Zabaikalskii Krai. Web-site of Zabaikalskii Krai's Regional Department of Federal State Statistics Service. http://chita.gks.ru/digital/region10/default.aspx. Accessed 10 October 2011 (in Russian)
State Report on ecological situation in Primorskii Krai in 2010. Official web-site of Authorities of Primorskii Krai, Department of natural resources and environmental protection. http://primorsky.ru/adms/isp/uprav/okrsred/doklad/. Accessed June 25 2011 (in Russian)
State Report on environmental conditions and protection in Zabaikalskii Krai in 2008-2009. Official web-site of Department of natural resources and environment of Zabaikalskii Krai. http://minprir.e-zab.ru/information/?mid=8098&id=8099. Accessed June 27 2011 (in Russian)

Statistical Bureau of Heilongjiang Province; Survey Office of The National Bureau of Statistics in Heilongjiang (2004) Heilongjiang Statistical Yearbook. China Statistics Press, Beijing, p 540
Statistical Bureau of Jilin Province; Survey Office of The National Bureau of Statistics in Jilin (2004) Jilin Statistical Yearbook. China Statistics Press, Beijing, p 550
Statistical Survey Office (1929) Manchuria: a statistical survey of its resources, industries, trade, railways and immigration. Tientsin, China, p 52
Sun KC (1973) The economic development of Manchuria in the first half of the 20th century. Harward University Press, Cambridge, p 124
Surin VI (1930) Forestry in Manchuria. Economic bureau of the C.E.R, Harbin. p 297+p 104 of Appendixes (in Russian)
Tarkhov S (2005) Changes of the administrative-territorial division of Russia in the XIII–XX centuries. Logos 6:66–101 (in Russian)
Tibekin AR (1989) Management and economics of agriculture in the Far Eastern economical region (1858–1985). Khabarovskoe knizhnoe izdatel’stvo, Khabarovsk, p 335 (in Russian)
Tkhorzhevsky II, Tsvetkov MA (1914) Atlas of the Asian Russia. Migratory administrarion. Saint-Petersburg, Russia, p 223 (in Russian)
U CJ, Li ZQ, Liang JC (1963) Economic geography of the North-Eastern China. Translated from Chinese. Publishing House of foreign literature, Moscow, p 359 (in Russian)
Wang Z, Zhang B, Zhang S, Song K (2005) Estimation of loss in ecosystem service values of Songnen plain from 1980 to 2000. J Geograph Sci 15:80–86
Wang Z, Zhang B, Zhang S, Li X, Liu D, Song K, Li J, Duan H (2006) Changes of land use and of ecosystem service values in Sanjiang Plain, Northeast China. Environ Monit Assess 112:69–91
Yamane M (2007) Overview of forest degradation and conservation efforts in the Amur basin in the twentieth century, with a focus on Heilongjiang province, China. In: Report on Amur-Okhotsk Project No. 4. Research Institute for Humanity and Nature, Kyoto, pp 111–122
Yamane M (2010) Temporal and spatial dynamics of human impacts on forest resources in the Amur river basin after the mid-twentieth century. In: Report of Amur-Okhotsk project No. 6 (Final Issue). Research Institute for Humanity and Nature, Kyoto, pp 291–310
Ye Y, Fang X (2009) Land use change in Northeast China in the twentieth century: a note on sources, methods and patterns. J Hist Geogr 35:311–329
Zabaikalskii Krai’s Regional Department of Federal State Statistics Service (2010) Socioeconomic situation in municipal districts of Zabaikalskii Krai. Zabaikalkraistat, Chita, p 144 (in Russian)
Zabaikalskii Krai’s Regional Department of Federal State Statistics Service (2011) Statistical yearbook of Zabaikalskii Krai. Zabaikalkraistat, Chita, p 299 (in Russian)
Zausaev VK (1984) Problems of development of the Far Eastern forest sector. Khabarovsky Publishing House, Khabarovsk, p 184 (in Russian)
Zhang Y (2000) Deforestation and forest transition: theory and evidence in China. In: Palo M, Vanhanen H (ed) World forests from deforestation to transition? Kluwer, Dordrecht, pp 41–65
Zhong M, Fan W, Liu T, Li P (2003) Statistical analysis of current status of China forest fire safety. Fire Safety J 38:257–269