Land Cover / Land Use Changes in Amur River Basin in the 20th Century (Russia, China, Mongolia)

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1. Introduction and Objectives

Observing the long-term LUCC changes in a certain region of the world is one of the interesting and important tasks of the LUCC studies. At the same time such observations are rather difficult, especially in the case of studying trans-boundary geographical objects, parts of which belong to different countries. The Amur River Basin is a good example of a trans-boundary trans-regional basin-type geographical structure. Its total area exceeds 2 millions km^2, 50 percent of its territory belongs to Russia, 42 percent to China and 8 percent to Mongolia.

Previous studies of the basin's territories in these three countries were significantly different. Investigations in the southern part of the Russian Far East in the 20th century were mostly oriented on the study of natural conditions – vegetation, soil, geomorphology, and others.

It is necessary to note that active surveys of the areas within the watershed of Amur River had begun already at the end of the 19th – beginning of the 20th century, and it is associated with names of such well-known travelers and scientists – naturalists as Venjukov M.I. Maak R.K., Maksimovich K.I., Przhevalsky N.M., Obruchev V.A. and others. Besides that, the Chinese part of Amur River watershed permanently attracted attention of Russian researchers. The works of Anuchin (1896, 1897) were ones of the first, which considered the combination of natural features, population and the economy of Manchuria.

A great volume of research works of both scientific, and scientific and applied character were fulfilled by the Amur Expedition, organized at the beginning of the last century (Krykov 1911; Korotkii 1912) to study the opportunity of economic development of Amuro-Ussuriiskii krai, further resettlement of peasants, and the development of trade and industry.

During the second part of the 20th century the works devoted to the economic and geographical characteristics of Manchuria were published (Anuchin 1948, Glushakov 1948).

An essential contribution to accumulation of extensive material about the differentiation of natural environment in Amur River watershed was made by the Russian-Chinese Joint Amur Expedition under the Council on Industrial Forces Organization of the USSR Academy of Science, and by the Heilongjiang Expedition of the People's Republic of China that carried out surveys in the second half of the 1950s (Nikolskaya, Chichagov 1957). The results of these surveys became the basis for fulfilling a whole series of thematic works, in which the natural environment of Amur River watershed was considered not only within the separate countries, but also as an integral geographical formation, parts of which are closely interconnected. Among those works it is necessary to mention the one about soil and geographical zoning of the Amur River by Liverovskii and Rubtsova (1962), a vegetation map of Amur River watershed (Sochava 1969; Sochava et al. (eds.) 1969), the work of Nikolskaya devoted to studies of morpho-structures of Amur River watershed (1972), among others. It is also necessary to point out the works of Murzaev (1955) and Efremov (1956) devoted to the characteristic of nature and economy of North-eastern China.

Modern interest in the studies of the trans-boundary watershed of the Amur River is manifested by the publication of papers devoted to the Program of sustainable land-use and rational distribution of land in the Ussuri River watershed (1996) and Khanka Lake (Kachur et al. 2001), to issues of its economic development (Baklanov, Ganzei 2004), to water and environmental problems (Ganzei, Mishina 2005), to land resources assessment (Karakin, Sheingauz 2004), and to trends of economic interaction between the Russian Far East and Northeastern China (Tattsenko 2006). The common feature of the works in recent years is that the analysis of the situation within the watershed was made as a rule by large units of administrative and territorial division situated on its territory. The use of such data is complicated because the information about separate parts of Amur River watershed is often incomplete, diverse, and dissimilar in details, methods of data collection and processing.

Land use was mostly characterized through statistical data without the mapping of wide territories. As a result, the works devoted to the LUCC in the region are few in number and their content is very heterogeneous. Data on land use changes in Eastern Mongolia are very rare and incomplete; we can even consider them to be unknown.

Northeastern China has been studied considerably more on the base of LUCC methodology. At the same time data available from the 20th century publications are widely diversified regarding the studied areas and duration of analysed periods. Generally, works predicting long-term changes are rare. One of few exceptions is the work of professor Himiyama. Under his leadership The Land Use Map of Northeastern China was compiled in 1995, allowing the study of spatial land use and land cover structure in the 1930s and the assessment of land changes for the 70-year period. As the basic source of land use information, Prof. Himiyama used topographical maps in the scale of 1:50,000 and 1:100,000 compiled by the Japanese military forces in the 1920s–1930s (Himiyama et al. 1995, 1997, 2002). In the Amur River Basin the compiled map covered its southern part – the most developed central plain of the Heilongjiang province, Jilin province, and the southern part of Inner Mongolia (in the Great Khingan Mountains).

2. Materials and Methodology

Historical land cover/land use map. Inventory of different materials containing information on land cover/land use in the 1930s–1940s in the Chinese, Russian and Mongolian parts

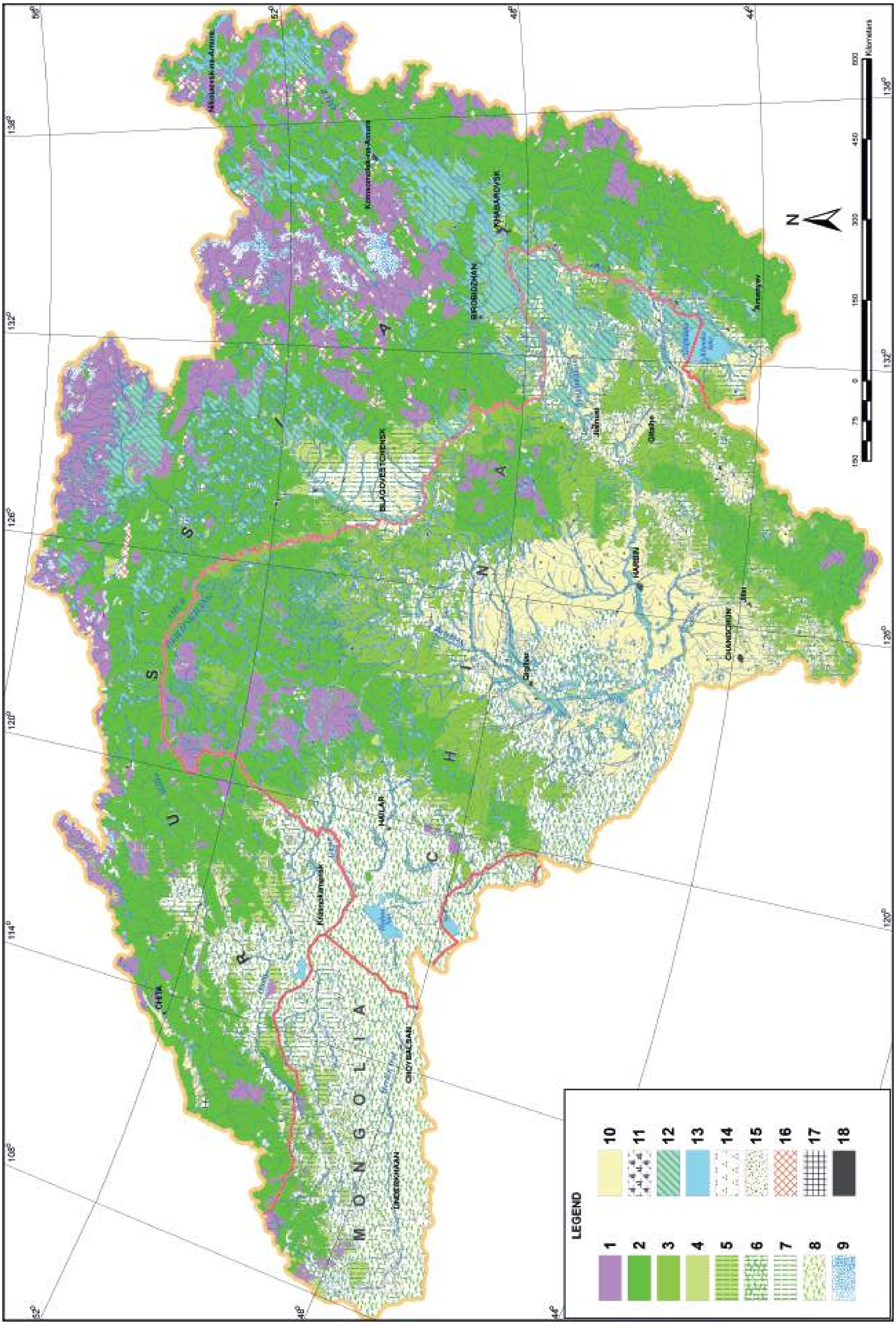

Fig. 1 – Land-use in Amur River watershed in the 1930s–1940s.
By figures are numerated: Forest lands: 1 – coniferous forest, 2 – mixed forest, 3 – deciduous forest, 4 – sparse growth; Scrub and Grassland: 5 – scrub and sparse growth, 6 – scrub and grassland, 7 – scrub, 8 – grassland; 9 – mountain tundra; Agricultural lands: 10 – dry lands, 11 – paddy field; Waters: 12 – wetland, 13 – lakes; Other lands: 14 – salt-marsh, 15 – sands, 16 – burned out forest, 17 – forest cutting area, 18 – urban land

of the Amur Basin showed that topographical maps published during the same period are the main source of land use data, and it is possible to compile the Land Cover Map of the Amur River Basin in the 1930s–1940s based them.

The map was compiled through analysis of topographical sheets of the Amur River watershed printed mainly in the 1930s–1940s in different countries in various scales (1:100,000, 1:200,000, 1:250,000, 1:300,000, 1:420,000 (10 versts in inch), 1:1,000,000). Totally it consisted of 1,327 topographical sheets.

The map of land use in the Chinese part of the watershed was compiled through an analysis of topographical sheets (scale 1:100,000), which were created for the Manchuria territory in 1930 by the General Staff of Kvantun Army of Japan. It was checked by the General Staff of the military-air forces of the USA using topographic maps in the scale 1:250,000 made for the Manchuria territory in 1949–1952. Being published in the USSR in the 1930s–1940s, the maps (scale 1:100,000 – 1:1,000,000) were also used to draw near border forest areas of China.

The Mongolian part of the watershed was characterized through an analysis of topographic maps in the scale 1:100,000, 1:200,000, 1:1,000,000 compiled in the USSR in the 1930s–1940s. Part of the maps in the scale 1:200,000 was republished in the early to mid 1950s on the basis of the maps in the scale 1:100,000, which were compiled in the late 1930s to the early 1940s.

To compile a map of land use in the Russian part of the Amur River watershed, the maps in the scales 1:100,000, 1:200,000, 1:300,000, 1:420,000 (10 versts in inch), and 1:1,000,000 were analysed. Part of the maps in the scales 1:100,000 and 1:300,000 was published in the 1950s. Such maps were used only for underdeveloped territories.

Maps in the **scale 1:1,000,000** allowed us to identify the following types of land cover: forest and non-forest land, wetlands, scrubs and sparse forest, large settlements, lakes and reservoirs. The maps in the scales 1:300,000 and 1:200,000 contain more detailed information about land cover and land use in the territory. We could identify additional characteristics such as type of forest (coniferous, mixed, deciduous – partly divided), grasslands, sparse forests and bushes, bushes & grasslands, forest cutting area, burnt-out forests, salt marshes, sand ground, dry lands, and settlements.

The content of American maps in the **scale 1:250,000** was considerably poor. These maps reflect forest areas without division into forest type, wetlands, and settlements. Generally these maps are the most schematic.

Maps in the **scale 1:100,000** show the same type of land cover and land use as on the 1:300,000 and 1:200,000 maps. Additionally these maps allowed to define the boundary between arable (dry) lands and paddy fields.

It is necessary to notice that the legends on the topographic maps published in Japan and in the USSR are essentially different. The legends on the Japanese maps are more detailed especially for the developed agricultural areas and they identify arable lands, rice fields, gardens, and plantings of Manchurian millet. With the exception of only some topographical sheets for the Mongolian part of the basin and the Chitinskaya Oblast in the steppe areas where arable lands were shown, these types of land use were practically not shown on the maps in the scale 1:100,000 published in the USSR. At the same time, it is necessary to mention that the system of conventional signs (legend) for topographic maps for the Manchuria territory is more complex and is non-uniform. So, for example, the conventional signs characterizing wetlands or bushes on different maps of the Manchurian series are often different. The area of the separate fields occupied with arable lands and paddy fields makes up less than 40 km^2. Such ranges are not shown on the map in the scale 1:2,500,000. In this case it is necessary to take into account that small size paddy fields dominate.

The Japanese maps for flat territories that were economically developed are distinguished with their accuracy and are compiled with a high degree of reliability. Therefore, the borders of agricultural territories are defined rather authentically. At the same time, topographic maps of mountain forest territories contain a lot of errors: in drainage network drawing, in the width of river valleys, in border position forest-nonforest territory, and in the characteristic of forests. Information on the adjacent lists often does not match one another properly that is especially visible on the type of vegetative cover.

For the Russian and Mongolian parts of the watershed, the borders of forested territories, wetlands, burnt-out areas, felling areas, meadows, sparse forests, shrubs and sparse forests, shrubs, mountain tundra, steppes, salt marshes, sand lands, water objects and large settlements are defined with a high degree of reliability. In most cases the borders of the types of forest lands (the coniferous, mixed and deciduous forests) have a presumptive character (for the whole watershed).

Modern land use map. A set of satellite images of Landsat-7 (USA) in 2000–2001 was the initial basic information for drawing the map "Modern Land-Use in Amur River Watershed". The composite compilations of the average resolution from 30 m and more were mainly used in the work. The satellite images of Landsat TM with a resolution 15–30 m were used to specify some of the most disputable territories. Image processing was made in GIS ArcView 3.3 software using a special extension Image Analysis to form shape files and their subsequent converting to Arc/Info coverings. Besides direct interactive expert decoding of satellite images, the following sources have been used as reference and correcting information converted to electronic raster and then to vector format: 1. a map of vegetation of Amur River watershed in the scale 1:2,500,000 edited by Sochava (1969), 2. a map of vegetation of the Mongolian National Republic in the scale 1:3,000,000 (1990), 3. a map of vegetation of China from the Vegetation Atlas of China in the scale 1:1,000,000 (2001), 4. raster topographical maps in the scale 1:500,000. According to a resulting scale (1:2,500,000), the objects with the area of 40 and more km^2 (that corresponds approximately to 2×3 mm on the map) and with the width 2.5 km (that corresponds to 1.0 mm on the map) were shown on the map.

First of all, it was necessary to make a uniform classification of types of land-use since the classifications accepted and used in the People's Republic of China, Russia and Mongolia essentially differ. Since the approaches to the mapping of land-use in Mongolia and in Russia are similar, here we give more details to the Chinese classification.

In the People's Republic of China the unified state classification of lands embracing various levels of analysis, from the small-scaled level up to the middle and large scaled level, are accepted. In total three classes, differing in detail, of description of typological characteristics of lands are used. The categories of lands of the first class reflect their most general properties allowing to allocate, for example, "cultivated lands", "forest lands", "meadows", "water bodies", "industrial lands", and "unused lands", and to generate from them a legend for drawing up of maps in the scale 1:2,500,000 and smaller. The maps made in the scale 1:1,000,000 use more fractional typological characteristics. For example, the type "cultivated lands" is subdivided into the subtypes "paddy fields" and "dry agricul-

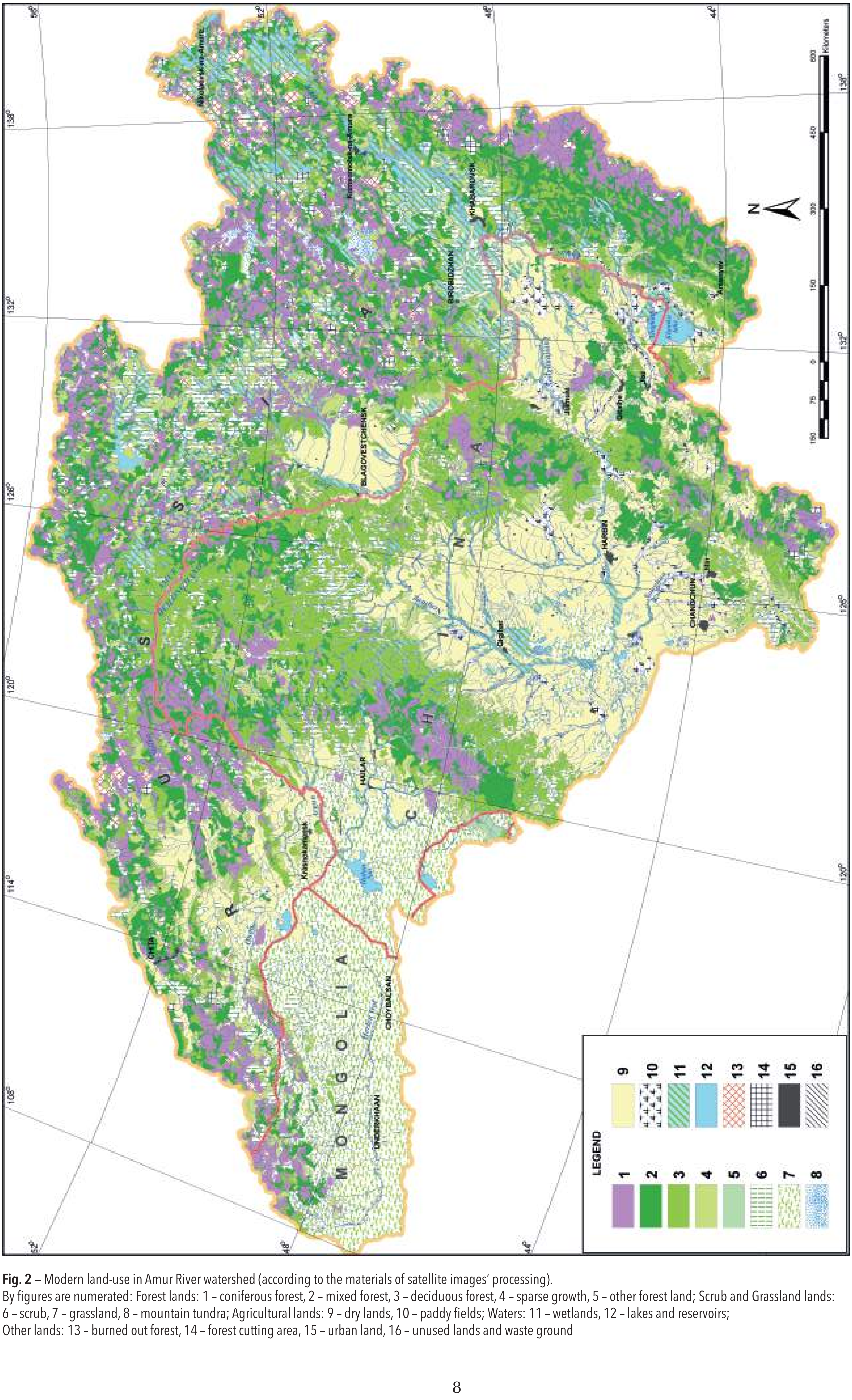

Fig. 2 – Modern land-use in Amur River watershed (according to the materials of satellite images' processing).
By figures are numerated: Forest lands: 1 – coniferous forest, 2 – mixed forest, 3 – deciduous forest, 4 – sparse growth, 5 – other forest land; Scrub and Grassland lands: 6 – scrub, 7 – grassland, 8 – mountain tundra; Agricultural lands: 9 – dry lands, 10 – paddy fields; Waters: 11 – wetlands, 12 – lakes and reservoirs;
Other lands: 13 – burned out forest, 14 – forest cutting area, 15 – urban land, 16 – unused lands and waste ground

tural lands" (arable lands). The forestlands and meadows are subdivided into subtypes depending on the density of wood stands or on the density of grassy cover. Thus, the territories with the density of wood stands over 30% belong to the forestlands; the territories with the density of stands from 10% to 30% belong to sparse forests, etc.

From our point of view, use of the state classification of lands accepted in the People's Republic of China for characterization of modern land use in Amur River watershed, narrows a volume of helpful information on character of economic activities in its limits though it essentially simplifies its mapping. In our country more complex and detailed typology of land-use (land tenure) has been accepted and realized in statistics. However, it practically was not applied to mapping of large territories because of its ambiguity.

The classification of forestlands has been corrected. In addition to the density of wood stands their typological characteristics have been introduced. The coniferous, mixed, deciduous forests, sparse forests, and other forests have been defined in forestlands as a result.

Since the scale of mapping is small enough, and the level of generalization is high, the type's concept includes various kinds of land-use and of the natural state of lands. At that, a genesis of each type of lands is not considered; they can be formed in very different ways.

The "coniferous forest" type includes fir, abies, Korean pine, pine, larch forests and their versions. The "mixed forest" type includes all transitive versions from coniferous to deciduous forests at their approximately equal ratio. The "deciduous forest" type includes broadleaved and small-leaved forests and their versions. The "sparse forest" type includes rare forests of various compositions, alternation of woods with bushes with density of stands less than 30%. At that, as already mentioned above, the genesis of these types of lands is not considered; they can be formed after fires, loggings, etc. The "other forest" type includes forest plantations, including industrial ones.

The category "meadows and bushes" embraces such types as meadows, bushes, and bushes with high-mountainous tundra. The "bushes" type includes bush, meadow and bush lands, and partly bush and sparse forested lands with a prevalence of bush vegetation. The "meadows" type is rather variable, and at the given stage of studies it includes any grassy vegetation – meadows, steppes, etc. The "mountain tundra" type includes mountainous pine, dwarf forms of high-mountainous bushes, and tundra.

The agricultural lands category embraces types of reclaimed and not reclaimed agricultural lands. The reclaimed lands include mainly paddy fields and not reclaimed lands – arable lands, fallow lands, haymaking sites, and pastures. The different water bodies form the "lakes and reservoirs" type. The "wetland" type includes swamps, high bogs and waterlogged flooded meadows and marches. Fire-sites and loggings in the places of former forests, residential areas (large settlements), industrial and unused lands (quarries, slag-heaps, etc.) enter to the category "other lands".

3. Results and Discussion

The thematic content of the topographical maps allows us to use 18 land use types for compiling the land cover map of the Amur River basin for 1930s–1940s (Fig. 1, Tab. 1). According to these data 53.1% of the basin were occupied by forest; 17.6% by grassland, 13.2% were covered by wetlands, and the share of dry land was 6.7%. Over 63% of the Basin's forestland, 57.7% of wetlands and about 72% of urban lands were situated in Russia in the 1930s–1940s, and 91.1% of dry lands and 55% of grassland in China.

Tab. 1 – Land Cover and Land Use in the Amur River Basin in the 1930s–1940s, thousand km²

Land Use type	Total area of land use type	Russian territory	Chinese territory	Mongolian territory
Coniferous forests	189.4	155.6	30.8	3.0
Mixed forests	686.9	495.4	179.4	12.1
Deciduous forests	180.6	17.1	163.4	0.1
Sparse forests	25.7	14.8	7.9	3.0
Sparse forests and bushes	64.4	31.6	20.5	12.3
Bushes	40.1	28.0	0.1	12.0
Bushes and grasslands	28.9	5.9	22.3	0.7
Grassland	358.4	46.0	195.2	117.2
Dry lands	136.8	12.2	124.6	
Wetlands	270.3	155.9	111.2	3.2
Lakes and reservoirs	9.1	5.6	2.9	0.6
Urban lands	0.3	0.2	0.1	
Forest cutting area	2.1	2.1		
Burned-out forests	17.9	17.7		0.2
Mountain tundra	21.3	21.0		0.3
Salt-marsh	5.1	1.0	0.3	3.8
Sand ground	2.3		2.0	0.3
Paddy fields	0.5		0.5	
Total area	2,040.1	1,010.1	861.2	168.8

Tab. 2 – Land Cover and Land Use in the Amur River Basin in 2000–2001, thousand km²

Land Use type	Total area of land use type	Russian territory	Mongolian territory	Chinese territory
Coniferous forests	277.6	214.0	8.4	55.2
Deciduous forests	316.0	118.3	3.1	194.6
Mixed forests	347.3	231.0	6.2	110.1
Sparse forests	145.4	106.3	4.6	34.5
Burned-out forests	27.2	26.4	0.5	0.3
Other forest lands	5.0		1.8	3.2
Grasslands	248.7	24.5	135.1	89.1
Paddy fields	26.0	2.4		23.6
Dry lands	346.7	81.1	2.3	263.3
Lakes	10.6	5.2	0.8	4.6
Reservoirs	2.5	2.0		0.5
Wetlands	140.0	95.3	0.1	44.6
Urban lands	2.7	1.0		1.7
Unused lands	0.7	0.6		0.1
Mountain tundra	13.3	12.8	0.1	0.4
Waste ground	0.2	0.2		0.0
Bushes	121.6	82.3	5.8	33.5
Forest cutting area	8.6	6.7		1.9
Total area	2,040.1	1,010.1	168.8	861.2

The map of the modern land use in the Amur River basin is more detailed in thematic contents and contour of different polygons (Fig. 2).

Modern features of land cover/land use in the basin. At present forest areas occupy over half (54.3%) of the watershed territory (Tab. 2). Over 30% of this area is occupied by mixed and coniferous forests situated mainly in the Russian territory. It is necessary to note that majority of fire-sites, loggings and sparse forest are also located in the Russian territory that reflects adverse trends in forest management, developed on our territory in the 1990s. Deciduous forests occupy about 15% of all forestlands.

The agricultural lands occupying nearly 20% of its territory are the second type of lands by area in the watershed.

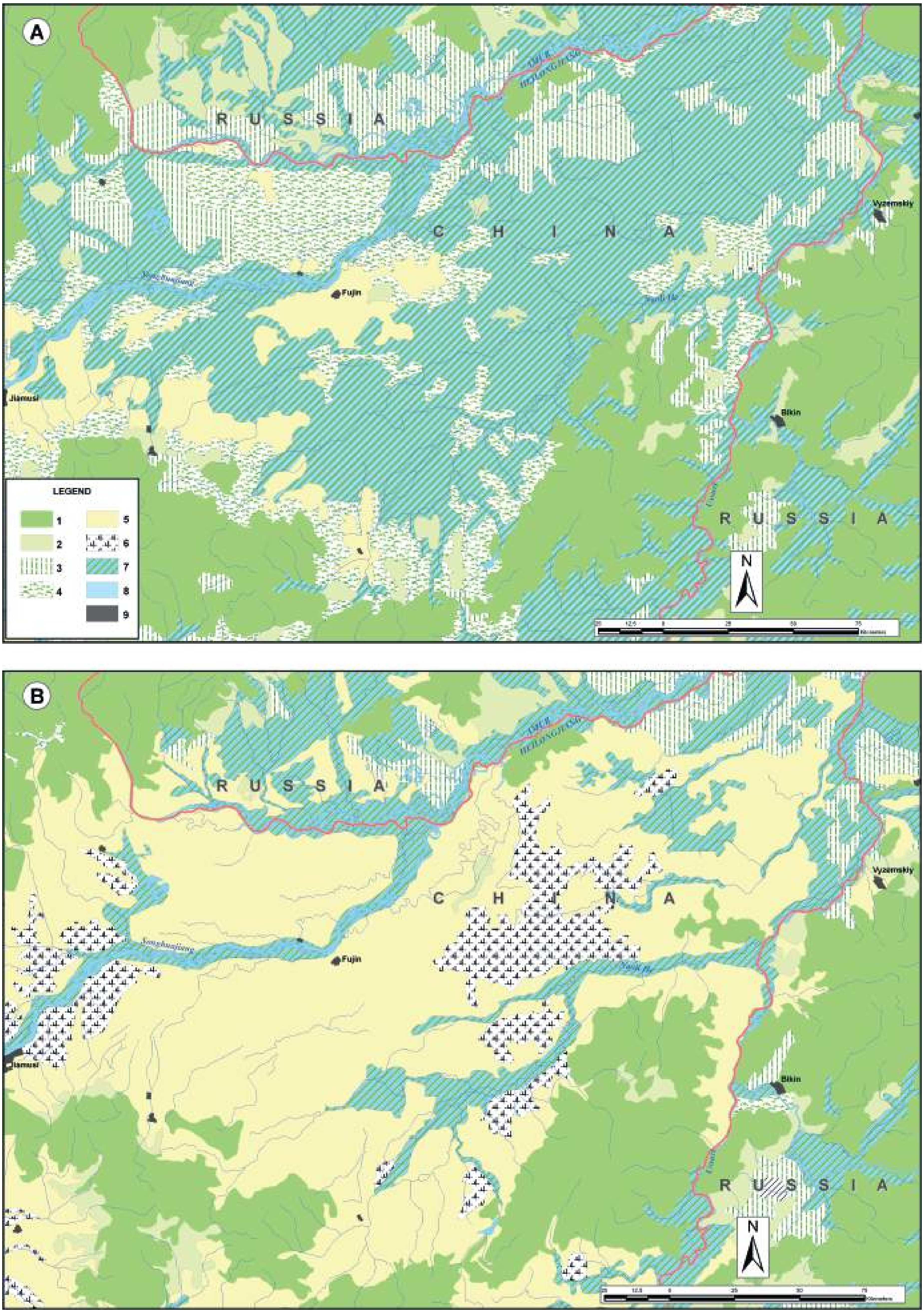

Fig. 3 – The Sanjiang plain. Agricultural land and wetlands: A – in the 1930s–1940s, B – at the beginning of the 21st century.
By figures are numerated: 1 – forest, 2 – sparse growth, 3 – bushes, 4 – grassland, 5 – dry land, 6 – paddy field, 7 – wetlands, 8 – lakes and reservoirs, 9 – urban land

The dominated share of cultivated lands including irrigated, is located in the Chinese part of the watershed. Prompt reduction of wetlands is one of the consequences of its active agricultural development. According to the Chinese researchers (Liu et al., 2004) a share of wetlands on the Sanjiang Plain for the period from 1950 to 2000 was reduced to 52.5%, from 32.4 thousand km² to 9.2 thousand km², at the same time the share of agricultural lands has increased from 10.2% to 55.1%. At that, the greatest part of the wetlands is still located on the Russian territory.

Meadows and bushes totally make about 20% of the area of the Amur River watershed.

The territorial distribution of types of modern land-use reflects both natural and climatic conditions of the territory, and also national features of nature management, historical and modern trends in the development of economy of the countries.

The main tracts of coniferous forests on the Russian territory are in Khabarovskiy Krai, Amurskaya and Chitinskaya oblasts – 73.4, 68.7 and 48.3 thousand km² correspondingly. The mixed forests are the dominating types of vegetation; their main share is concentrated in the same administrative units. Deciduous woods prevail in the Amurskaya Oblast, Khabarovskiy Krai and in the Chitinskaya Oblast. The Amurskaya Oblast also takes a leading position in the area of sparse forests (39.9 thousand km²) and in the area of meadows and bushes vegetation (36.2 thousand km²).

Wetlands are widespread in Khabarovskiy Krai and in Amurskaya Oblast, 48.6 and 28.2 thousand km² correspondingly. The area of wetlands in Primorskiy Krai is much less, 6.8 thousand km².

The main tracts of lands used in agricultural production are situated in the Chitinskaya Oblast (38.2 thousand km²) and in the Amurskaya Oblast (25.1 thousand km²). Irrigated lands prevail in the Primorskiy Krai that is associated with rice growing in several frontier areas.

The forests most subjected to fires are in Khabarovskiy Krai. There are 16.1 thousand km² of burnt down or dead forest that makes 61.5% of the area with similar land on the Russian territory. Their share in the Amurskaya and Chitinskaya Oblasts is also great – 18.4% and 16.6% correspondingly.

The most active logging activity is in the Khabarovskiy Krai and in the Amurskaya Oblast. At that, the share of the logging area in Khabarovskiy Krai exceeds over 2 times the same average share in other regions of the Russian part of the Amur River watershed.

On the Chinese territory, coniferous forest occupies the largest area within the Great Khingan Ridge in the Inner Mongolia Autonomous Region – 25.3 thousand km². The area of coniferous forest in the Heilongjiang Province is 22.5 thousand km². Mixed forests prevail in the Heilongjiang Province with 59.7 thousand km² that makes 54.2% of the area of these forests on the Chinese territory. The share of mixed forests in Inner Mongolia Autonomous Region and in Jilin Province is less – 32.5% and 13.3% correspondingly. The Heilongjiang Province also has the largest areas of deciduous forests with 105.2 thousand km². Sparse forests and bushes are most widespread in the Inner Mongolia Autonomous Region that is caused both by natural and climatic features in the territory, especially in its southern part, and by industrial logging of timber within the Great Khingan Ridge till 1998. Processing of satellite images allowed us to reveal the other feature of the modern state of forests on the Chinese territory. We observed a considerable divergence between the data of the Atlas of vegetation of the People's Republic of China

Tab. 3 – Integrated legend for the comparison of land cover / land use in the Amur River basin

1930–1940	2000–2001	Common legend
Conifer forest Mixed forest Deciduous forest	Conifer forest Mixed forest Deciduous forest Other forest land	Forests
Sparse growth Scrub & sparse forest	Sparse forest	Sparse forest
Bushes Bushes & Grassland	Bushes	Bushes
Grassland	Grassland	Grassland
Dry land	Dry land	Dry land
Paddy field	Paddy field	Paddy field
Wetland	Wetland	Wetland
Lakes	Lakes & Reservoirs	Lakes & Reservoirs
Urban land	Urban land	Urban land
Forest cutting area	Forest cutting area	Forest cutting area
Burned out forest	Burned out forest	Burned out forest
Mountain tundra	Mountain tundra	Mountain tundra
Salt-marsh Sands	Unused land Waste ground	Unused land

Tab. 4 – Land cover and land use changes in the Basin

Land use type	1930–1940	2000–2001	Change	1930–1940	2000–2001	Change
	thousand km²			%		
Forest land	1,056.9	945.9	−111.0	51.8	46.4	−5.5
Sparse forest	90.1	145.4	55.3	4.4	7.1	2.7
Bushes	69.0	121.6	52.6	3.4	6.0	2.6
Grassland	358.4	248.7	−102.6	17.2	12.2	−5.0
Dry land	136.8	346.7	209.9	6.7	17.0	10.3
Paddy field	0.5	26.0	25.5	0.0	1.3	1.2
Wetland	270.3	140.0	−130.3	13.2	6.9	−6.4
Lakes & reservoirs	9.1	13.1	4.0	0.4	0.6	0.2
Urban land	0.3	2.7	2.4	0.0	0.1	0.1
Forest cutting area	2.7	8.6	6.0	0.1	0.4	0.3
Burned-out forest	17.4	27.2	10.0	0.9	1.3	0.5
Mountain tundra	21.3	13.3	−8.0	1.0	0.6	−0.4

(2001) and the decoded data. For example, the northern part of the Great Khingan Ridge is shown in the Atlas of vegetation as a zone of practically continuous distribution of coniferous forests. However, the decoded data show that at present deciduous forests dominate there, and coniferous and mixed forests are typical in the central and southern parts of the Great Khingan Ridge.

A high share of timber cuttings in the Jilin Province – 36.3% of the logging area in the Chinese part of the watershed appeared to be also unexpected. It is necessary to note that the center of timber cuttings in the People's Republic of China has moved to the artificial forests, partly created for these purposes. Besides that, it is necessary to take into account that the data used cannot reflect the present situation in full because the objects of an area of at least 50 km² were not displayed on the final map, actually forest tracts of the smaller areas are frequently cut down.

Significant portions of agricultural land, reclaimed land, and wetlands of the Chinese part of the Amur River watershed are situated in the Heilongjiang Province (its shares are 63.1%, 67.8% and 58.3% of the total area of the corresponding land type on the Chinese territory). It is interesting to compare the data on irrigated lands, received as a result of processing of satellite images, and the official statistical data. A large part of irrigated lands in the Heilongjiang Province is used for rice growing. Statistical data show (Heilongjiang Statistic Yearbook, 2001) that in the Heilongjiang Province in 2001, paddy fields occupied 1,598 thousand hectares, the decoded data

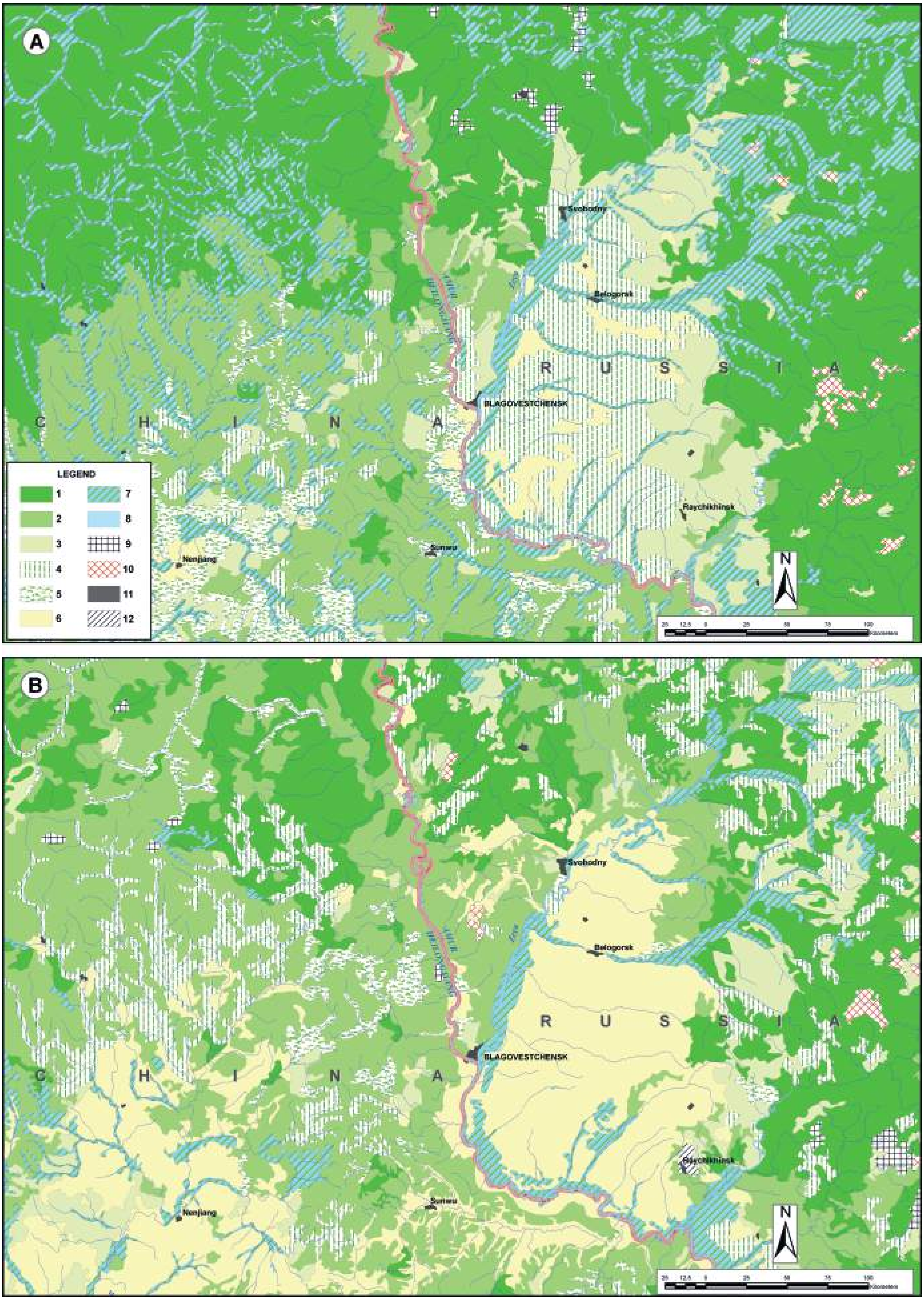

Fig. 4 – The Xioxing Anling and Zeya-Burea plain. Forest and Scrublands: A – in the 1930s–1940s, B – at the beginning of the 21st century.
By figures are numerated: 1 – coniferous and mixed forests, 2 – deciduous forest, 3 – sparse growth, 4 – bushes, 5 – grassland, 6 – dry land, 7 – wetlands, 8 – lakes and reservoirs, 9 – forest cutting area, 10 – slash fire, 11 – urban land, 12 – unused land

(1,600.9 thousand hectares) practically completely coincide with these figures.

In the Mongolian portion of the Amur River watershed the forested territories are situated in Hentei, Tuva and Dornod Aimaks. At that, most parts of the coniferous, mixed and deciduous forests are located in Hentei Aimak – 79.1%, 82.1% and 49.3% of the area of these forests of the whole Mongolian part of basin correspondingly. There are also 73.5% of sparse forests, and nearly 51% of bushes in this portion of the watershed.

Dornod Aimak is also characterized with a wide spectrum of land-use. Deciduous forests dominate among forested lands, which share makes 24.7% of these forests in the Mongolian portion of the watershed. The share of coniferous and mixed forests is much less – 5.6% and 2.3% correspondingly. Sparse forests and bushes are widely distributed – 21% and 43.5%. Approximately half of the meadows in the Mongolian portion of the watershed is concentrated in this Aimak. There are also 86.5% of its agricultural lands.

Despite the small area of Tuva Aimak in the Amur River watershed (5%), over 15% of coniferous and mixed forests, 26% of deciduous forests, and 8% of meadows and bushes of the Mongolian portion of the Amur River watershed is distributed there.

Long-term dynamics of land cover/land use in the basin. For estimation of the dynamics of spatial distribution of various types of land cover/land use in the basin, it was necessary to compare the legends to the maps that were different from one another.

Tab. 3 provides the scheme of generalization of land use type. All subtypes of forestland were grouped in the land use type – forests. Sparse forests and scrub and sparse forests were combined in sparse forests. Scrub, scrub and grassland were combined in bushes. Salt marsh, sand lands and unused land and waste ground are presented in the common legend as one land use type – unused land.

As a result, the maps "Modern land-use in Amur River watershed" in the scale 1:2,500,000, compiled as a result of processing of the satellite images Landsat TM, and "Land Cover and Land Use in the Amur River Basin in 1930–1940" allowed us for the first time to assess the character, structure, national features of land-use on the territories of Mongolia, the People's Republic of China and Russia, included in the Amur River watershed from unified positions and in uniform scale. The Chinese portion of the watershed is the most economically developed one.

Comparison of the two compiled maps shows essential decreasing of the area and simplification of the structure of forests towards a prevalence of invaluable woods (Tab. 4). Especially it concerns the northern and eastern parts of the Great Khingan Ridge, Less Khingan (both in the Russian, and Chinese portions), the northern portion of the Sikhote-Alin Ridge, and Chitinskaya Oblast. These changes resulted from the active policy on industrial timber cutting that existed on the Chinese territory of the watershed until the end of the 1990s, proceeding timber cuttings on the Russian territory, and also forest fires, annually arising, especially on the Russian territory. 78% of the cut down forests in the Amur River watershed and 97% of the burned forests were in 2000–2001 on the Russian territory. In total, forests lost 111.2 thousand km^2 of the area since 1930. On the other hand, we have observed the increasing of the area of sparse forests (2.7%) and bushes (2.6%), forest cutting areas (0.3%), and burned out forest (0.5%).

A significant expansion of the area of agricultural lands that occurred in the People's Republic of China between the 1930s and 2000–2001 has been observed. These changes primarily concern the Sanjiang Plain (Fig. 3), the Xioxing Anling, and the Zeya-Burea plain (Fig. 4). In many cases it is associated with the reduction of the area of wetlands and forests. Wetlands lost 130.3 thousand km^2 in the basin. The biggest part of the wetlands is still concentrated in the Russian part of the watershed

Tab. 5 – Threats and causes of ecosystem degradation due to land use dynamics in the Amur River Basin (Simonov, Dahmer 2008)

Ecosystem	Major threat	Source	Outcome
Aquatic habitats of the Amur River and its larger tributaries	Pollution	Population growth, economic development, and lack of sanitation facilities, especially in Heilongjiang Province of China; insufficient sanitation facilities in large Russian cities	Contamination of waterways by phenols from decomposition of organic materials; declining abundance of aquatic fauna
	Energy development and water management	Construction of the Bureya hydroelectric station; plans for new hydroelectric stations on the Amur and other rivers	Disruption of natural hydrological regimes; loss of seasonal habitats for aquatic fauna
	Overfishing	Salmon fishing by commercial marine fishers; unrestricted fishing in China; inadequate legislation and lack of enforcement mechanisms in Russia; absence of socio-economic conditions to introduce sustainable fishing mechanisms	Declining fish stocks; inability of fish populations to recover; loss of livelihood for minority communities; potential extinction of commercially valuable species
Wetlands of the Amur River Basin	Energy development and water management	Regulation of water flow from hydroelectric stations and dams dyke construction along river banks, excessive water consumption by agriculture	Wetland dehydration, habitat loss and degradation loss of seasonal waterfowl breeding and fish spawning habitats loss of aquifer recharge capacity of wetlands
	Fires in floodplain forest-grassland habitats	Traditional annual burning of pastures and hay fields, thought to increase productivity	Destruction of nestlings of ground-nesting birds, especially cranes; loss of nesting and brood-rearing habitats; mortality of woody seedlings inhibits forest recovery
	Timber harvest	Cutting of remnant relic forests for firewood by local people	Reduction of forest cover
	Agriculture and animal husbandry	Wild land conversion to farmland, wind erosion of the humus layer from agricultural lands; overgrazing, runoff of soils and animal waste from farms	Loss of wild land area; increased soil loss and water turbidity; Eutrophication of water bodies
	Over-exploitation of wildlife. Anthropogenic wildfire	Unregulated hunting of migratory birds in wintering areas in China; poaching and non-sustainable use of game resources in Russia; decrease and fragmentation of nesting habitat.	Decrease in numbers of wild animals
Forests	Timber production	Clear cutting and unsustainable logging	Decline in area of old-growth forests
		Selective cutting of valuable species	Ecosystem degradation
		Pioneer-style unsustainable logging practices; anthropogenic forest fires	Disappearance of forests after clear cutting on unstable mountain or permafrost soils; Ecosystem degradation Declining forest cover; declining forest wildlife, increased erosion, impacts on water bodies
	Over-exploitation of resources	Illegal hunting and collecting	Disappearance of rare species of plants and animals; decrease in prey base for large predators; conflicts between humans and large predators; habitat loss
	Unregulated resource exploitation	Commercial mining; energy development	Transformation of native ecosystems; reduction of floodplain forests during gold mining operations; flooding of forests with creation of the Bureya hydroelectric station

(in Amurskaya Oblast, Evreiskaya Autonomous Oblast and Khabarovskiy Krai).

Risks to ecosystem degradation. The causes and threats of ecosystem degradation due to long term land use dynamics in the Amur River Basin are connected with both the natural and human factors (Tab. 5).

All issues mentioned above are related to one another. But the most significant impact to ecological quality of regional development is manifested by wetland degradation and the decrease of forest area. Wetlands are treasures of the biodiversity and provide habitat for plant and animal species. They are extremely valuable assets that serve many environmental, social and economic functions: wildlife habitat, pollution purification and flood mitigation. Even so, systematic wetland conservation is lacking and policy gaps have caused the destruction of wetlands in recent decades. Reclamation and excessive water use, over grazing, forest and steppe fires, timber harvest and fires, wind erosion and agricultural chemicals and industrial waste lead to degraded or a complete loss of wetlands.

Reclamation transforms wetlands into arable land, including paddy fields and it is the most serious threat to wetlands. Many reclamation projects are either completed or in process. Wetland degradation and loss of biodiversity resulting from reclamation are irreversible or require substantial periods of time. Development of plains and flood lands result in fragmentation and isolation of small tracts of lakes and swamps which decreases the remaining threatened wetlands.

Forestland productivity continues to decline and forests in the region are losing their water holding, climatic and wildlife habitat functions. The basic fires arise in the fields where there is little snow, in the spring from the end of April to the middle of May, and in autumn from mid October to the end of November. As a result of fires of different character and frequency, forests of all types sharply change their structure. In broad leaf forests, there are ground fires at which the potent leaf-litter burns down more often. The process of regeneration is different compared to fires in coniferous forests. In places of the dead trees (oak, linden, maple), young springwood is recovered, mainly oak and alder in downturn of relief. Fires do not directly lead to the death of large predators and ungulates, but do force them to leave burnt out territories.

4. Conclusions

Thus, in the limits of trans-boundary river basins all distinctions in economic and nature protection policy of the neighbouring countries are developed with a greater force. The parts of the trans-boundary basin of one country can test the essential negative influence of unreasonable decisions in land use policy of other countries. The essential distinctions in land-use on the territory of countries belonging to Amur River watershed stipulate an existence and development of sharp trans-boundary environmental problems. Among them are the impoverishment of biodiversity, disturbance of migration ways of wild animals and their forage reserve, fragmentation and partial destruction of habitats, increased fire danger, high risk of flooding, contamination of surface waters, and water and atmospheric transfer of polluting substances.

Overall it is possible to allocate the most typical consequences of trans-boundary influence on land use policy (Baklanov, Ganzey 2008):

1. Preservation of the uniformity and interrelation of nature-geographical structures and processes in different parts of trans-boundary basins.
2. Preservation of a certain coherence of nature-resource structures in different parts of the trans-boundary basins.
3. Formation of asymmetric territorial structures of land use, consisting in their distinctions on the different sides of the border.
4. Formation of asynchronous processes and tendencies of land use: during the same periods of time the tendency and processes of land use on the different sides of the border, as a rule, differ.
5. The river has an important function of an ecological and geographical axis in the basin since the ecological condition of the river appreciably reflects an ecological condition of the whole trans-boundary watershed.
6. Formation in the trans-boundary basin of two-parts land use structures as possible interfaces of nature-resource and economic objects on the different sides of the border.

The compiled electronic maps give, firstly, an information basis for carrying out of further analysis of the land-use system in the Amur River watershed, and, secondly, as an electronic layer they make a component of forming geo-information space of the whole Amur River watershed.

Therefore, studying the complex problems influencing the efficiency of land use and ecological state in the trans-boundary river basins, and also the factors breaking their structural organization and functioning, is one of the primary goals for development of the program of sustainable land use that should be created for trans-boundary basins.

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