THE LANDSCAPE CHANGES AFTER 1930 USING TWO KINDS OF LAND USE MAPS (1930 AND 2000)

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INTRODUCTION

The Amur River watershed is a very large, trans-boundary geo-system that includes portions of Russia, China, Mongolia and North Korea. This region is characterized by diverse natural systems and abundant natural resources. The region is characterized by various land use types: forestry, agricultural, industrial and transportation. The main types of land use in the Russian and Chinese parts of the Amur River basin are agricultural and forestry ones. These land use types are the primary factor in the transformation of the natural and natural resource systems of the Amur River watershed. An analysis of these transformations begins with the fact that the Amur River watershed is a large, intact geographic system (geo-system, ecosystem). The natural and ecological processes underway in separate areas of the watershed are closely interconnected, and the anthropogenic impacts and other changes occurring there have an impact on the geo-system as a whole (Baklanov, Ganzey, 2008).

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

Previous studies of the basin's territories on 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, soils, geomorphology, and others. The common feature of the works is that the analysis of situation within the watershed was made as a rule by large units of administrative and territorial division situated on its territory. 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 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 the Eastern Mongolia are very rare and incomplete; it is even possible to call them unknown.

Northeastern China is studied considerably better on the base of LUCC methodology. At the same time data available from publications of the 20th century are widely diversified regarding the studied areas and duration of analyzed periods. Generally, works estimated long-term changes are rare. One of exceptions was set by works of professor Yu. Himiyama. Under his leadership The Land Use Map of the Northeastern China has been compiled in the 1995, allowed to study spatial land use and land cover structure for the 1930s and assess land changes for the 70-years period. As 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 1920-1930s (Himiyama, 1997; Himiyama et al., 1995; 2002). In the Amur River Basin compiled map covered its southern part – the most developed central plain of Heilongjiang province, Jilin province, and the southern part of Inner Mongolia (in the Great Khingan Mountains).

MATERIALS AND METHODS

The Land use/Cover map for 1930-1940s has been compiled through analysis of topographical sheets of the Amur River watershed printed mainly in the 1930-1940s of the last century 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 made up 1,327 topographical sheets.

The map of the Chinese part of the watershed has been compiled through analysis of topographical sheets (scale 1:100,000), which were compiled for Manchuria territory in 1930 by the General Staff of Kvantun Army of Japan. Being published in the USSR in the 1930 – 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 analysis of topographic maps in the scale 1:100,000, 1:200,000, 1:1,000,000 compiled in the USSR in the 1930-1940s.

To compile a map of land use in the Russian part of the Amur River watershed, the maps of scales 1: 100,000; 1:200,000; 1:300,000; 1:420,000 (10 versts in inch), and 1:1000,000 were analyzed. The part of the maps in scales 1: 100,000 and 1: 300,000 was published in the 1950s. Such maps were used only for underdeveloped territories.

A set of satellite images of Landsat-7 (USA) in 2000-2001 of the average resolution from 30 m and more mainly have been used in the work for drawing the map "Modern Land-Use in Amur River Watershed". More detail this work was described in our previous publication (Ganzey et al., 2007).

DISCUSSION OF RESULTS

One of the key questions of this study is that of the reliability of comparisons obtained. In our opinion, one can say with high level of confidence about only general tendencies in the spatial dynamics of land distribution within the Amur River basin. Over a long period of time, the Amur River basin has been the focus of geopolitical interests of Russia, China and Japan. These interests have essentially deepened by the mid-1930s which has manifested itself as a number of boundary military disputes and, later on, resulted in the large-scale hostility. The geopolitical desires were, to a large extent, based on the economical interests of countries related to intense development of the basin' natural resources: forest, land, mineral, water etc.

Peculiarities of the modern land use in the basin. Figure 1 shows data characterizing the peculiarities of land distribution in Chinese and Russian territories of the

Amur River basin. The largest areas along both sides of the border are occupied by forest lands, which share (with sparse forests) is approximately 46 % of Chinese area and 67 % of Russian area. Though, while a half of Chinese forest lands are covered with broadleaved tree species and the share of mixed and coniferous forests makes 28 % and 14 % correspondingly, in Russian Far East mixed and coniferous forests predominate (67 % in total). Sparse forests as a separate land category, shrubs and wetlands are more widespread in the Russian territory, their area and share of categories in the structure of lands overcome related Chinese indexes twofold in average.

The Chinese part of the basin is characterized by a large share of cultivated lands (33 %), approximately 8 % of which are presented by meliorated lands largely used as rice fields. The area of cultivated lands in the Russian part of the basin is 7 times smaller than this on Chinese territory. A peculiar feature of the Chinese part of the basin is widespread meadowlands, which share in the total area equals 10%. The other side of the border is marked for relatively large areas of burned out forests (2.8 %) and mountain tundra (1.5 %), as well as for major part of forest cuttings and unused lands. A number of polygons, reflecting various land types on the map, are in 2 times higher on the Russian territory in relation to the Chinese territory. Correspondingly, an average area of contour in the Chinese part of the basin more than twofold exceeds dimensions of the polygons at the opposite side of the border. In total, the number of contours covering every land type is characterized by a high level of correlation (0.9) with the area occupied by corresponding land type for both parts of the Amur River basin.

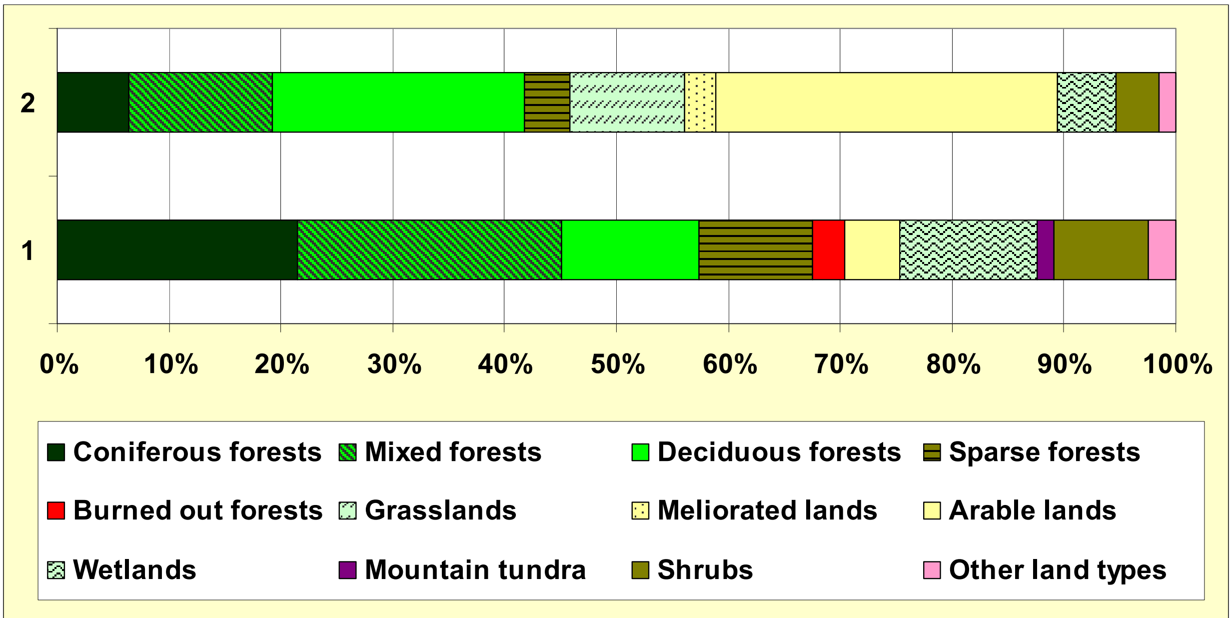


Figure 1. Land types of the Far Eastern (1) and Chinese (2) parts of the Amur River basin in 2000-2001

In the distribution of land types by number of polygons the following features can be noted. An average number of polygons of 1 land type in Russian and Chinese parts of the basin are 73 and 144 correspondingly. Along both sides of the border the composition of five primary land types, leading by number of polygons, is similar. It includes 3 forest types and woodlands, together with shrubs on Russian side and plough lands on the Chinese side. Though it's worth mentioning about the discrepancies observed in this group between a number of polygons and total area of a certain land type. Thus in the Russian part of the basin the sparse forests just a little fall back to mixed forests in the number of polygons, while the latter, covering 23 % of the whole Russian area, more than twice overcome the area of sparse forests. On the Chinese area the arable lands, being the most frequent land type (30.6 %), have less number of polygons than mixed and broadleaved forests. These and other differences are also noticeable for average size of polygons of this or that land type.

The largest average polygon area in the Chinese part of the basin belongs to arable lands, broadleaved forests, meadows and wetlands, the difference in the number of polygons of the four types of lands being almost threefold. On the Russian territory the predominating lands are arable lands and wetlands together with coniferous, mixed and deciduous forests, though the range of average polygon area differs only twofold.

Average area of polygons on the Russian side overcomes the magnitudes of water bodies, coniferous forests, unused lands and waste lands, burned out forests and forest cuttings, mountain tundra on the Chinese side. These land types, excluding coniferous forests, are of relatively small total area. By others widespread land types in the basin, average polygon size is larger on the Chinese territory. But the correlation between average size of the polygons of various land types in the Russian and Chinese parts of the basin is more diverse. It is also revealed by comparing the dimensions of total areas of certain land types and the number of their polygons. Thus, on the Chinese side the total area of arable lands is sevenfold higher than on the Russian, the number of units of the land category is three times higher, and the average area of their contour is twice higher. The situation with broadleaved forests differs a little. Their area in the Chinese part of the basin is twice larger than at the opposite side of the border, while the number of polygons is only one-third higher, and the average area of the polygon overcomes the Russian parameter threefold. Wetlands and coniferous forests, having considerable difference in total area and the number of polygons with its predomination at the Russian side, do not differ that much in the average size of the polygons. It is also interesting that for sparse forests and shrubs the average area of polygons on the Chinese side is 1.5-2 times higher than on the Russian side, while within the range of the latter the indicated land categories are twice more widespread, and the number of polygons is 3.5-3.8 times higher than on the Chinese territory. It is also worth mentioning that average sizes of contours of forest cuttings and burned out forests on the Russian territory are 1.4 times higher than on the Chinese territory. It is logical to suppose that average size of a polygon for a certain category is relatively close related to the total area of a land type and the number of polygons. Though along the both sides of the Amur River the average size of polygons of various land types is of low correlation with the indicated parameters what can be most likely stipulated by an intensive economic impact.

Thus along both sides of the border the composition of five primary land types, leading by number of polygons, is similar. It includes 3 forest types together with shrubs on Russian side and arable lands on the Chinese side. The largest average polygon area in the Chinese part of the basin belongs to arable lands, broadleaved forests, meadows and wetlands

Chinese study area is characterized by simpler typological land structure on the level of separate transboundary geosystems. Related complication of the spatial structure and simplification of the typological structure is considered as ecologically negative situation, as it means too much fragmentation of natural territorial complexes. On the Russian territory the predominating lands are arable lands and wetlands together with coniferous, mixed and deciduous forests. The spatial structure of the "pattern" of the lands is of more complex character on the Russian side. It is also expressed by a bigger amount of contours and their smaller sizes. Correlation between average size of the polygons of various land types in the Russian and Chinese parts of the basin is more diverse. It is also revealed by comparing the dimensions of total areas of certain land types and the number of their polygons.

Comparison of the two compiled maps (*Fig. 2, Fig. 3*) shows essential decreasing of the area and simplification of structure of forests towards a prevalence of invaluable woods (*Table*).

Table: *Land cover and land use changes in the Basin*

Land use type	1930-1940 (km^2)	2000-2001 (km^2)	Change (km^2)	1930-1940 %	2000-2001 %	Change (%)
Forest land	1057016	945812	-111204	51,8	46,4	-5,5
Sparse forest	97306	145397	48090	4,8	7,1	2,4
Bushes	68703	121598	52894	3,4	6,0	2,6
Grassland	351270	248664	-102606	17,2	12,2	-5,0
Dry land	136783	346696	209913	6,7	17,0	10,3
Paddy field	546	25982	25437	0,0	1,3	1,2
Wetland	270251	139929	-130322	13,2	6,9	-6,4
Lakes & reservuors	9087	13112	4026	0,4	0,6	0,2
Urban land	309	2666	2358	0,0	0,1	0,1
Forest cutting area	2689	8655	5967	0,1	0,4	0,3
Burned-out forest	17423	27365	9943	0,9	1,3	0,5
Mountain tundra	21144	13177	-7967	1,0	0,6	-0,4

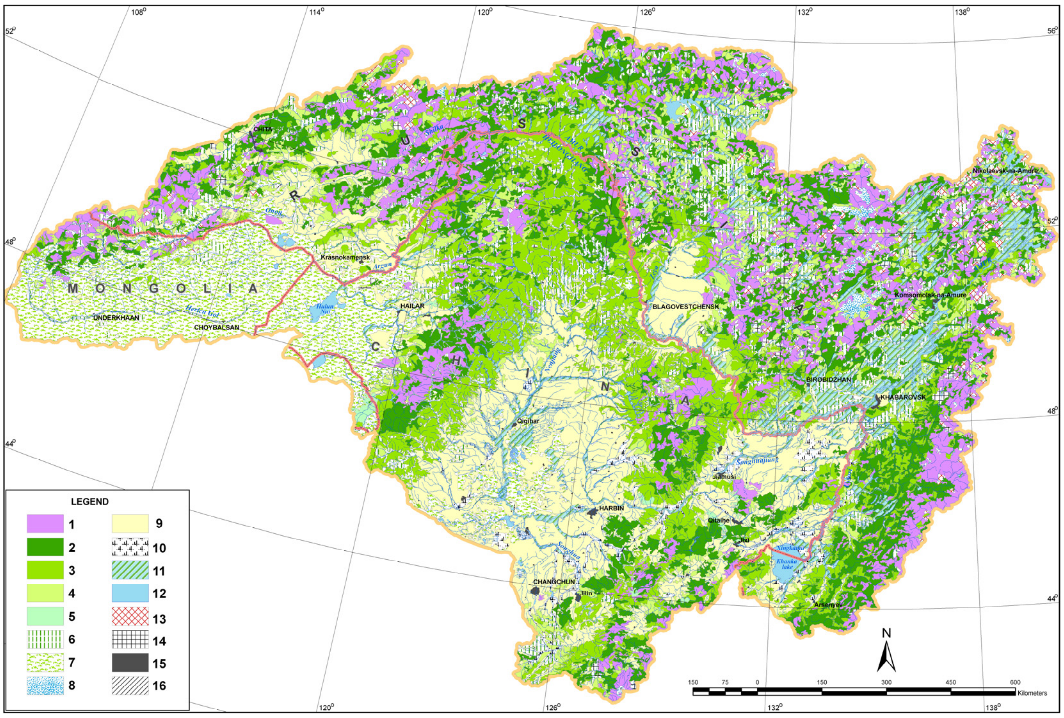


Figure 2. Modern land-use in Amur River watershed (according to the materials of decoding satellite images).
By figures are numerated: Forest lands: 1 - coniferous forest, 2 - mixed forest, 3 - deciduous forest, 4 - sparse growth, 5 – other forest land; scrub and grassland lands: 6 - scrub, 7 - grassland; 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

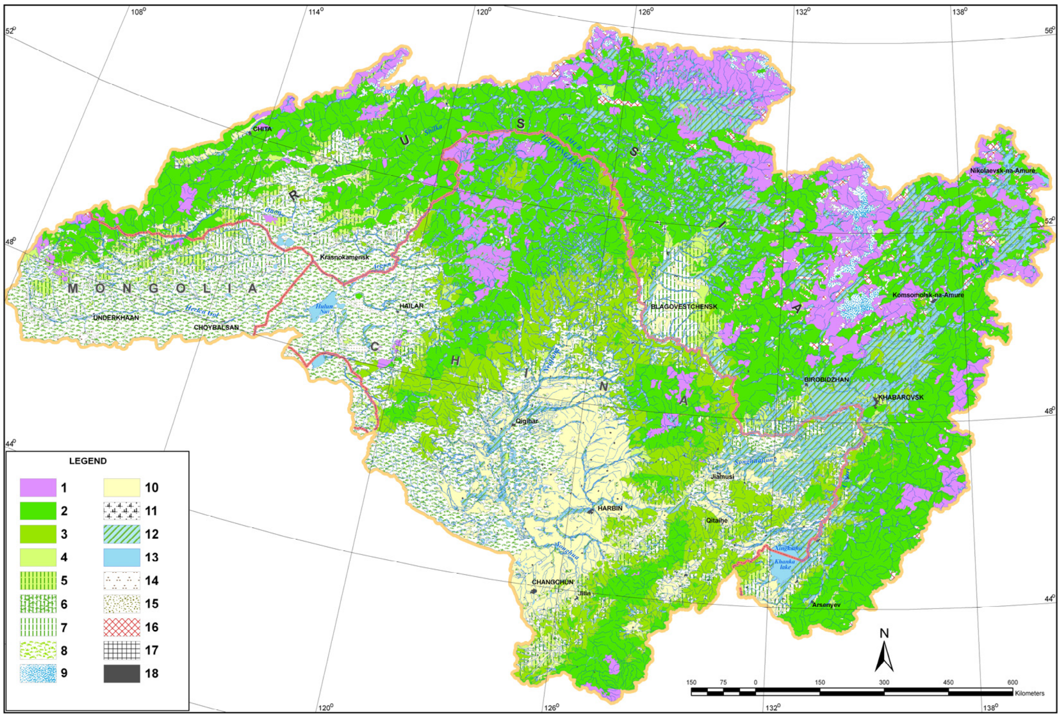


Figure 3. Land-use in Amur River watershed in 30-40 years of XX century.
By figures are numerated: Forest lands: 1 - coniferous forest, 2 - mixed forest, 3 - deciduous forest, 4 - sparse growth; Scrub and Grassland: 5 - scrub and sparse growth, 6 - scrub and grassland, 7 - scrub, 8 - grassland; 9 - mountain 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

Especially it concerns to the northern and eastern parts of the Great Khingan Ridge, Less Khingan (both in Russian, and in Chinese portions), northern portion of Sikhote-Alin Ridge, and Chitinskaya Oblast. These changes resulted from active policy of industrial timber cutting existed on the Chinese territory of the watershed up to the end of the 1990s last century, 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 Amur River watershed and 97 % of the burned forests are 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 may observe the increasing of the area of sparse forests (2.4 %) 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 Chinese People's Republic in the 1930s and in 2000-2001 has been observed. These changes at first concern the Sanjiang Plain, and the Xioxing Anling and Zeya-Burea plain. In many cases it is associated with reduction of the area of wetlands and forests. Wetlands lost 130.3 thousand km^2 in the basin. Most part of wetlands is still concentrated in the Russian part of the watershed (in Amurskaya Oblast, Evreiskaya Autonomous Oblast and Khabarovskii Krai).

Forest lands. A.S. Sheingauz (2006) has identified several periods in the economical use of the Far-Eastern forests noting meanwhile the complex spatial-temporal dynamics of volumes and heaviness of felling. From 1900 to 2000, he has revealed two peaks of felling which have coincided with periods of 1930-1940s and 1980s. During first of these periods, the most intense felling were noted in the Zeya-Bureya plain and Amur-Zeya Plateau, Amur Oblast, and on the western macroslope and foothills of the central and southern Sikhote-Alin, Primorsky Krai. By 2000, a zone of intense felling has shifted to the northern part of Sikhote-Alin and it has also remained quite high within the Little Khingan. A.S. Sheingauz notes that the Amur zone of intense felling has disappeared by 2000. This fact has also found confirmation in our cartographic estimates of the spatial dynamics of forests and their felling within the Amur River basin (*Fig.* 4).

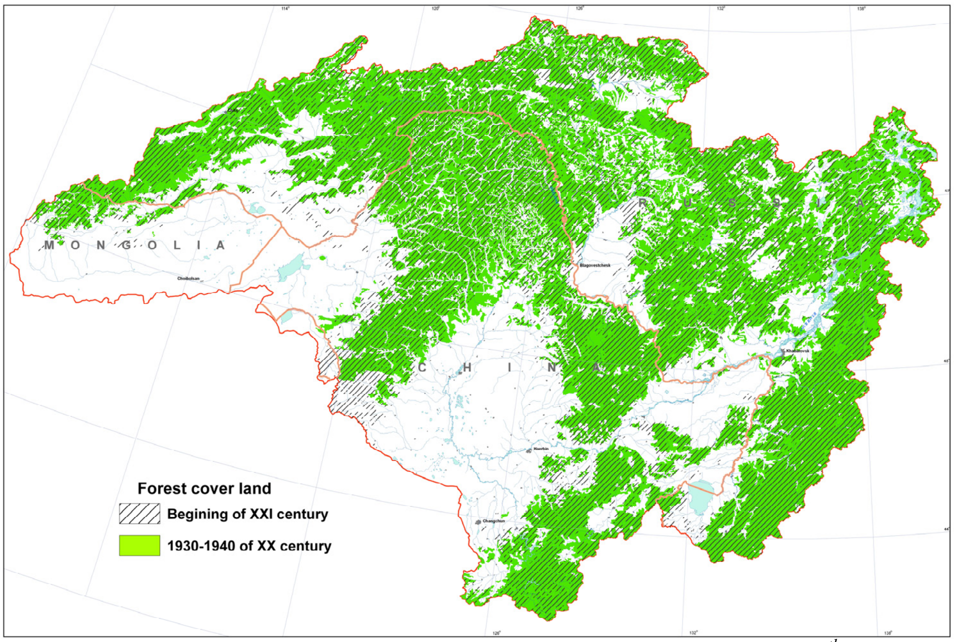


Figure 4. Dynamics of the forest lands in the Amur River Basin in XXth century.

In the Chinese portion of the basin, the basic felling of 1930-1940s was concentrated around the mountain massif of Changbaishan and Little Khingan ridge which was partly related to the construction and subsequent operation of the railway between Harbin and Jiamusi (*Heilongjiang forests, 1993)*. From 1931 to 1945, the forest area within the Little Khingan and Sungari River basin has decreased by more 10.1 million ha (Masanobu, 2007). Over the period of 1949 to 1998, the area of forest land in the Autonomous Area of Inner Mongolia has decreased by 5 % while it has increased by 5-10% in Heilongjiang and Jilin provinces. Basic felling has been made on the north-western slopes of Little Khingan ridge as well as in its middle part. From 1950 to the mid-1980s, about 1/7 of total volume of timber harvested in the PRC has fallen on the Heilongjiang province. The north-eastern PRC has remained in the XX century one of main suppliers and consumers of timber. According to our data, the forest lands within Amur River basin have decreased over the analyzed period by 945.8 thousand km^2. The area of forests has, to the largest extent, decreased on the western and eastern spurs of the Great Khingan mountains, in western and northern Sikhote-Alin Ridge, within the Little Khingan ridge (Russian and Chinese parts) and in Amur and Chita Oblasts. Though this process was characterized by the stable negative trend, there are regions where the forests have arisen owing to the active reforestation police. First of all, it concerns the southern part of the Great Khingan ridge

Agricultural lands. The cleared forest areas were often used for the farm production. So, according to data of K. Nakagane (1982), the area occupied with crops in three north-eastern provinces of China has increased for a period of 1932-1942 by 17.7 %. This figure agrees with estimates of the Russian geographers (Glushakov, 1948). The particularly great growth was noted for areas sown to soya (by 21-27%), kaoliang (21%) and millet (by 18 %). The lands sown to rice have increased on the average by 2%. The expansion of the area under cultivation was to a large extent related to the continuing development of the Nongjiang-Sungari lowland and southern, most suitable for agriculture, portions of the North Khanka plain.

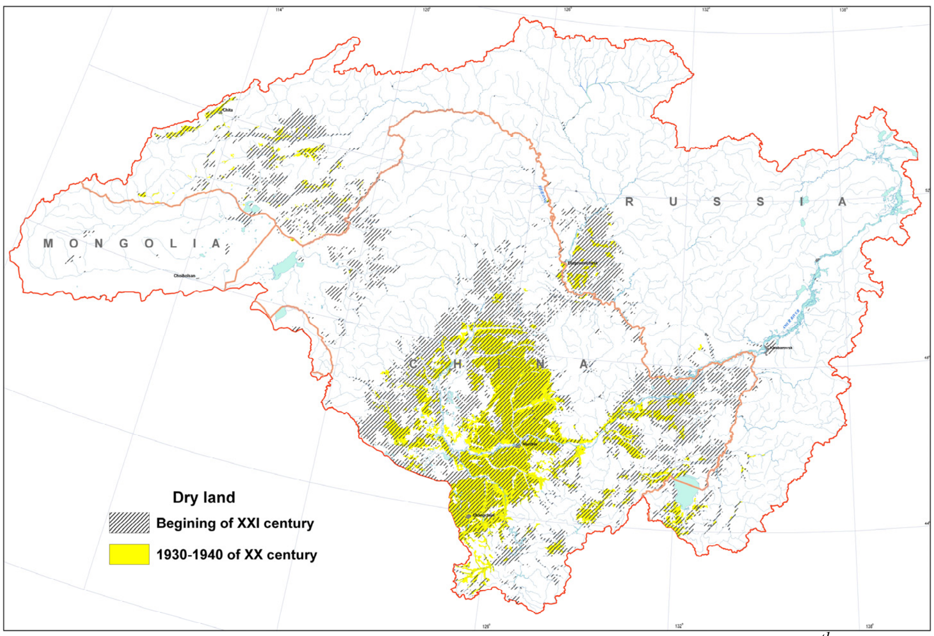
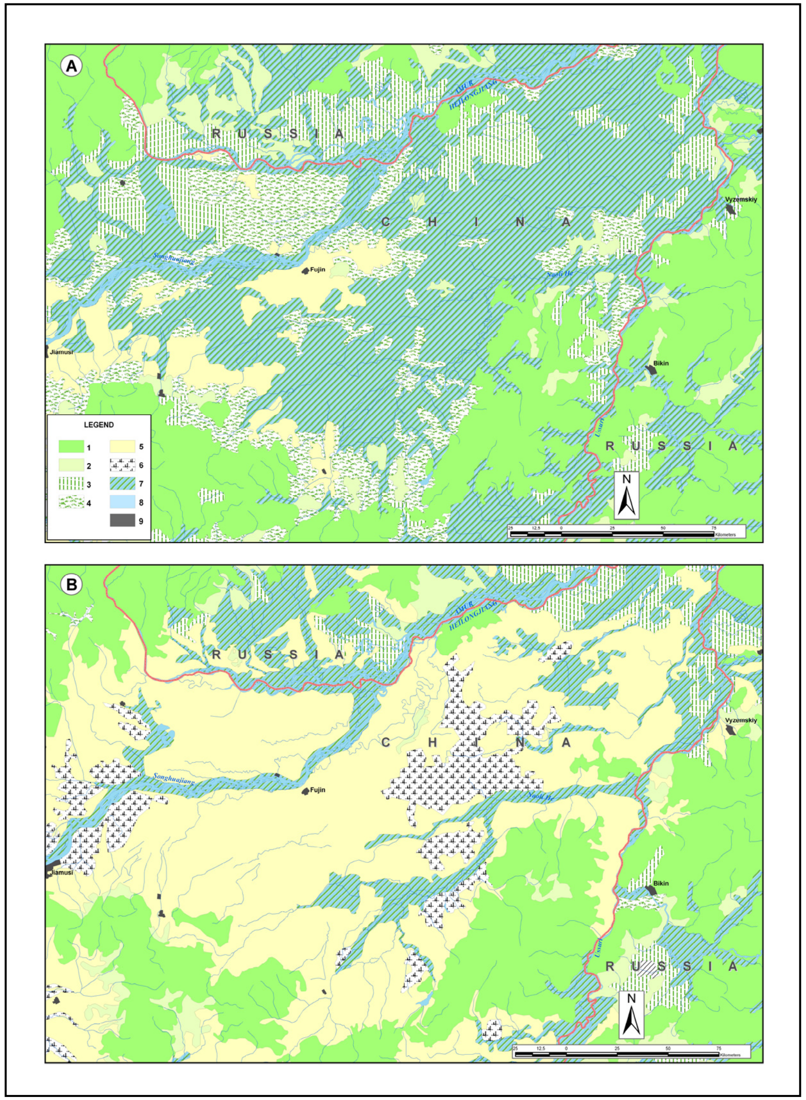


Figure 5. Dynamics of the dry (arable) lands in the Amur River Basin in XXth century.



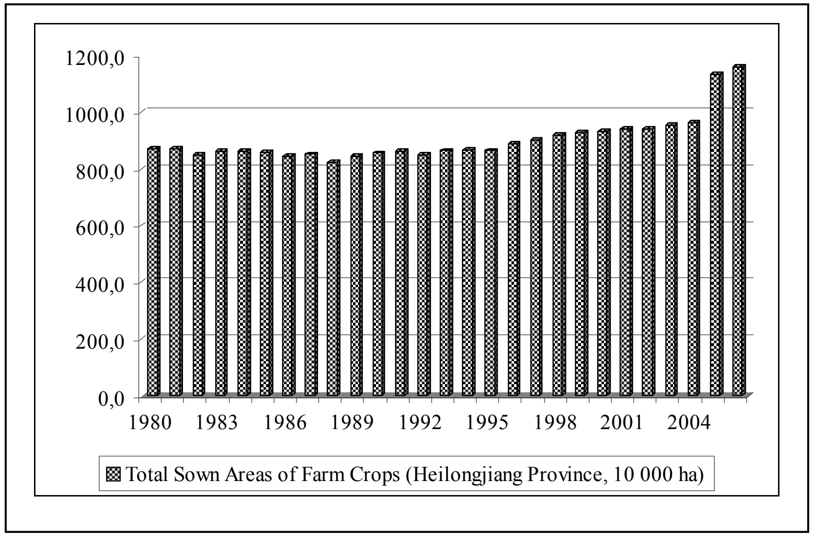


Figure 7. Dynamics of sown areas of farm crops, Heilongjiang Province (10000 ha)

Figure 6. The Sanjiang Plain. Agricultural and wetland lands: A - in 1930-40 years of XX century, B – at the beginning of XXI 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

According to data of A.R. Tibekin (1989), the areas under crops for a period of 1930-1940 have increased by 57.3% in Amur Oblast and by 66.7% in Khabarovsk Krai (Russian territory). In Primorsky Krai, they have decreased by 13.3% in connection with the resettlement of Koreans to the Central Asia and Kazakhstan. The Zeya-Bureya plain, Khanka and Middle-Amur lowlands were subjected to the most development. On the whole, the stable tendency to increase in the area of agricultural lands has observed in all parts of the basin (*Fig.* 5).

In the last ten years, different tendencies of the agricultural development of lands dynamics within the basin were observed. In the Russian part of the basin, there was a decrease in areas under crops as compared with the pre-crisis period while, in the Chinese one, new territories were developed. On frequent occasions, this development was related to the conversion of the water-marsh and meadow lands to agricultural ones. This process was characterized by the most intensity on the Sangjiang plain (Liu et al., 2004; Wang et al., 2006). From 1980 to 2000, the areas of meadows and water-marsh lands of the Nongjang-Sungari lowland have reduced by more than 25% and 8.5% respectively. The changes on the Sangjiang plain were more essential – from 1950 to 2000, the area of water-marsh lands has decreased by 52.5 % while that of arable land has increased by 45 % (*Fig. 6, 7*).

Fires. The fires within the Amur River basin occurred over the whole period of its development. With growth in population and development of new forest areas, their number has increased. If, after the catastrophic fire in the northern Gear Khingan ridge in 1987, the strict measures for the fire safety observance were taken in the Chinese territory, then the fires within the Russian territory remain one of the main factors affecting the dynamics of forests. In some years, the forests burn down over areas exceeding the felling territories. In the Heilongjiang province, the forests have burned down on the territory of 36 million ha from 1950 to 1990 (Masanobu, 2007). Unfortunately, this figure for the Russian territory is much more. A general trend for a growth in the forest fire area over a period of 1960-2000 is stable (Forest complex…, 2005). In the Russian part of the basin, a shift of fires from Amur Oblast to Chita Oblast is revealed for 70-year period under study, however Khabarovsk Krai remain a leadership in the area of fires.

CONCLUSION

Therefore, the cartographic analysis of the pattern of land distribution within the Amur River basin over the last 70-80 years, numerous investigations of Russian and foreign authors and statistical data allowed us to confirm and characterize quantitatively the basic tendencies of spatial variations of land use within the great subregional transboundary geosystem. The general tendency in the land distribution change is characterized by a reduction in area of natural lands (forests, water-marsh lands, meadows) and a swift increase in the anthropogenically transformed landscapes – agricultural landscapes, burnt-outs and coupes.

By our opinion, the sustainable nature management should be understood as the major component of the sustainable development of territory. Under sustainable nature management within this or that territory (or water bodies), including transboundary one, those volumes and ways of extraction and development of all territorial combination of natural resources are understood that can be carried out during the long period of time with minimum ecological damage and with high economic efficiency. At that changes of natural and resource potential (first of all its reduction) remain minimum ones.

To evaluate opportunities for sustainable land use, including within the Amur River watershed, there is a need for internationally based research programs that focus on the border areas of international trans-boundary regions. We connect a continuation of this study with the geoecological and cartographic analyses of disturbing the natural complexes, development of the scientific recommendations concerning the landscape planning within the international transboundary basin of the Amur River. Belonging of this territory to one river system of the Amur River basin, common structures and functioning of its landscape framework conditions close interrelation of ecological processes on a vast area. It is demanded to take into account all these phenomena in the models of inexhaustible nature use and sustainable development. It seems that within trans-boundary basins it is necessary to aspire to extremely possible agreement and coordination in regional nature use and sustainable development of boundary areas.

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