

Functional Zoning of Transboundary Geosystems for Development of Programs of Ecologically Sustainable Nature Management

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Abstract: A necessity of supplementing the method for transboundary diagnostic analysis with functional zoning of territory (landscape planning) on the basis of the analysis of the landscape organization of territory has been shown. The similar approach has been realized on an example of Pogranchny- Taipingling physical- geographical region (Russia- China), implemented on the basis of decoding spectral- zonal space images of Landsat- TM.

Key words: transboundary area; landscape; functional zone; diagnostic analysis

Last decade in the development of programs of sustainable nature management for transboundary territories the studies of geosystems of different types like river, lake, sea, wood, wetland, steppe, etc. are carried out. Structurally these works consist of two interconnected parts named correspondingly as “transboundary diagnostic analysis” and “strategic actions program” to carry out the principles of sustainable development (nature management). Methodological principles of the analysis of environmental problems, incorporated in transboundary diagnostic analysis, in many respects determine efficiency of implementation of the strategic actions program. However, from our point of view the method of carrying out a transboundary diagnostic analysis should be added with environmental and geographical maps, and with functional zoning of the territory under analysis on the basis of analyzing the territory's landscape organization. Isachenko A.G. has defined three main principles of optimizing landscape systems: 1) establishment of protection regime; 2) combination of regulating any resource use and measures on keeping an ecological balance within the territory; and 3) prevention of negative consequences for nature and people.

A geographical (cartographical) embodiment of these principles is the map of functional zoning of international transboundary territory, which creation in our opinion is the primary goal of transboundary diagnostic analysis that is unfortunately not done in many similar studies. The map of functional zoning represents a scientifically proved composition of territorial distribution of lands of various assignments and of nature management regimes.

Principles of sustainable nature management of territory assume conservation of natural resource potential of the using territory or even its increase. Therefore, functional zoning should be accompanied by definition of the priority, allowable and forbidden kinds of economic use within the territory under analysis.

Separate elements of the similar analysis of territory have been incorporated in the works of Isachenko A.G., Doncheva et al., Akhmeteli A.M., Beruchashvili N.L., Kochurov B.I., Dyakonov K.N., Mirzekhanova Z.G., et al. Great contribution to the development of the principles and methods of landscape planning have been made in the works associated with the Institute of Geography of the Siberian

Branch of the Russian Academy of Science under the leadership of Antipova A.N. Developing methods of landscape planning set by German geographers, they published a number of summarized works where the methodical approaches to planning and sustainable nature management of territory being developed by domestic geographers have been taken into account.

Drawing up a map of functional zoning consists of several stages. The sequence of the analysis of territory for functional zoning meets a principle of accumulation of knowledge about territorial landscape organization, natural resources potential, types of its economic use and disturbances made in the course of economic activities.

One of the difficulties arising in studying transboundary territories in the south of the Far East of Russia is a lack of information on features of social and economic, and ecological situations in the adjacent Chinese territory, especially at local level of the analysis. In this connection, application of remote sensing methods has great importance in the analysis of transboundary territories. Modern computer technologies allow us to use various satellite images of different spatial resolution. The integrated character of the information which is contained in satellite images enables to study geographical systems of various hierarchical levels, their structure and dynamics. At that, it is necessary to point out at high reliability, accuracy and efficiency of the received information. Use of satellite images and their analysis allow us to solve a problem of comparison of the data received at the same time and through one method.

Research range Principles of functional zoning (landscape planning) are implemented on an example of Pogranichny- Taipingling physical- geographical region that is a part of Primorskii- Laoyeling province. This region of 11903.1 km² is divided by the state boundary. The area of the Chinese part makes 6719.18 km², and Russian one is 5183.93 km². The region is a part of Khanka transboundary territory which includes Khankaishii and Sredne-Ussuriiskii economic districts on the Russian territory and Jixi economic district on the Chinese side.

In the geomorphological respect, the Russian part is represented by a system of low- mountainous ridges of the northeast direction (Pogranichny, Snii ridges) and lesser ridges of northwest direction (Komissarovskii, Alexeyevskii, Cheryomukhov, Sakharnaya Golova and other ridges). The main part of the territory has heights between 300 and 500 m above sea level, though its separate tops reach 600 - 700 m above sea level. The maximum height reaches 963 m above sea level (Kedrovaya Mountain). The general increase in relative heights from Khanka Lake to the west, and from the south to the north is observed. Most part of the territory is located in the watershed of Komissarovka River, running into Khanka Lake. The southern part of the territory is in watersheds of Melgunovka and Razdolnaya rivers.

The Chinese part is bounded by Suifen river valley in the south, and by Mulinghe river valley in the west. The mountainous ridges there also have the northeastern spreading. Taipingling (Mulingwojilin) Ridge is a continuation of Pogranichny Ridge on the Chinese territory. The absolute heights there are a bit higher than on the Russian territory, and they reach 1104 m above sea level in the southern part of the territory (Dapengshan Mountain). The general downturn of relief from the south to the north and from the east to the west is observed.

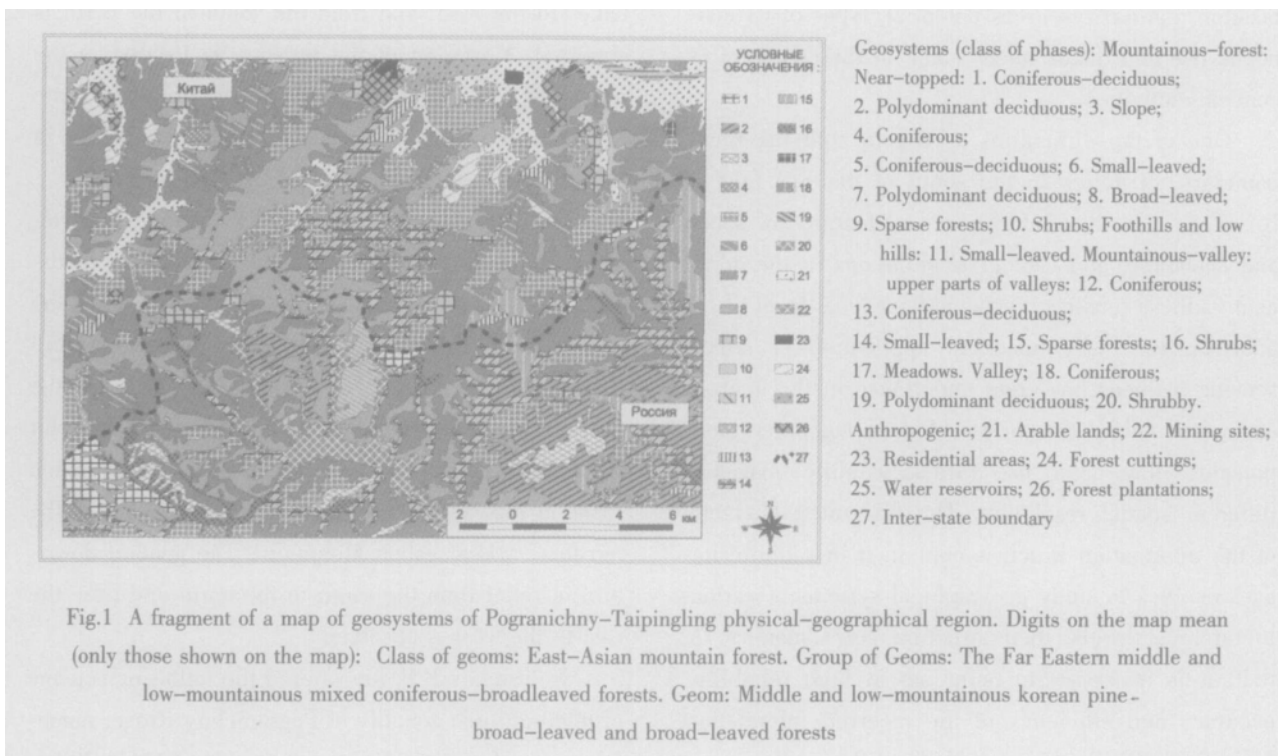
Kolesnikov B.P. has offered the following scheme of high- altitude zonality of Pogranichny Ridge, namely: zone of forest- steppe vegetation (up to 150~200 m above sea level), and zone of korean pine - broadleaved forests (up to 700~750 m above sea level) where broadleaved oak forests grow up to 600~650 m. The stepped oak- black birch sparse forests and the thickest heterophyllous hazel spread on slopes of southern exposition up to 500~550 m above sea level. A belt of fir- broadleaved forests is over 700~750 m above sea level. Fir- broadleaved forests and korean pine forests occupy small areas in some rivers heads, and korean pine forests mixed with stepped oak and pine forests and pine forests form a wide belt. Mountainous forest brown podzolic and brown mountainous forests undeveloped soils prevail there.

The most widespread formation of broadleaved forests in the area under survey is formed by mongolian oak forests. The forests with prevalence of Amur linden occupy insignificant areas on spurs of Pogranichny Ridge. Urusov V.M pointed out that korean pine – broad-leaved forests in the basin of Komissarovka river were repeatedly logged and suffered from fires. As a whole, it is necessary to note that the observed regularities of distribution of high-altitude zonality and species composition of forests are typical in the Chinese part of Pogranichny -

Taipingling physical- geographical region as well.

Functional zoning of transboundary territories (landscape planning) Decoding of spectr- zonal images of Landsat- TM in 1999–2001 with 30 m spatial resolution has been made to reveal modern spatial differentiation of geosystems of the physical - geographical region under survey.

Fig.1 shows a fragment of a map of geosystems on the territory under survey. The quantitative characteristics of landscape organization of the territory are given in Tab.1 The row of parameters suggested ear-



lier has been used to describe quantitative characteristics of landscape structure.

In a whole, it is necessary to note that more types of geosystems (due to anthropogenous) are observed on the Chinese territory. Its landscape structure is more shattered there, and on the average it has a smaller area of contour and greater complexity factor of organization of landscape structure, the main cause of that is more intensive and various economic use there.

The objects of current economic use in the surveyed territory are both natural ones like coniferous, coniferous- deciduous, deciduous, broad - leaved and

small - leaved forests, lakes and rivers, and ones transformed in the result of previous economic activities like sparse forests, bushes, meadows considerably. Anthropogenous objects like waste lands and burns, arable lands, forest cuttings, mining sites, settlements, forest plantations and water reservoirs are separately defined.

The area of coniferous forests on the Chinese territory is approximately five times more than that on the Russian one (Tab.2), coniferous- deciduous forests considerably exceed the similar parameters on the Russian side both by area and by share of occupied area. As a whole, these two objects of land use on the

Tab.1 Some quantitative characteristics of landscape structure of Pogranichny–Taipingling physical–geographical region (by Plyusnin V.M., 2003)

Parameters	Russian part	Chinese part
1	2	3
The number of landscape contours (n)	2624	3790
The number of geosystems types (m)	44	48
Average number of contours per one type of geosystems $p = n / m$	59.64	78.96
Index of fractionality of landscape contours $k = n / s$	0.506	0.564
Average area of contour $s_0 = s / n$	1.98	1.77
Coefficient of compicacy $k = n / s_0$	1325.25	2141.24
Entropic measure of landscape patterns compicacy $H = - \sum S_i / S \log_2 (S_i / S)$	3.96	3.61
Maximum possible compicacy of geosystem $H_m = \log_2 m$	5.46	5.59
Absolute organization of geosystem $H_i = H_m - H$	1.5	1.98
Relative organization of geosystem $R = 1 - H / H_m$	0.27	0.35
Sum of coefficients of landscape fragmentation $K_p = M / P$ (Ivashutina, Nikolaev, 1969)	1.99	1.35
Coefficient of fractionality-compicacy (Ivashutina, Nikolaeva, 1969) $K_c = K_p(A - S_{max}) / S A$	7.07	7.33

Tab.2 Modern economic use of lands in peripheral zone of Khankaiskaya transboundary territory

Objects of nature management	Russia			China		
	Area, km ²	Area, %	Number of polygons	Area, km ²	Area, %	Number of polygons
Coniferous forests	25	0,48	28	136,6	2,03	224
Coniferous-deciduous forests	102,6	2	69	754,7	11,24	619
Deciduous forests	1282,1	24,73	809	920,5	13,7	704
Broad-leaved forests	1143,1	22,05	776	494,7	7,36	511
Small-leaved forests	502,3	10	252	200,6	2,99	163
Sparse forests	707	13.64	346	512	7.62	324
Meadows	60.5	1.18	24	363.7	5.41	208
Shrubs	1110	21.41	179	505	7.52	204
Arable lands	214.3	4.13	113	2024.1	30.13	103
Settlements	30.1	0.58	21	174.4	2.6	93
Water reservoirs	-	-	-	11.5	0.17	8
Mining sites	6.2	0.12	5	1.3	0.02	3
Burns	0.6	0.01	1	-	-	-
Forest plantations	-	-	-	491.8	7.32	410
Forest cuttings	-	-	-	113.3	1.69	210
Waste lands	-	-	-	13.2	0.2	6
Total	5183.8	100.33	2623	6717.4	100	3790

Chinese territory make up of 13.3%, while only 2.5% on the Russian one.

Modern shape of the Russian territory determined by deciduous and broad-leaved forests occupies 46.8% of the whole territory (on the Chinese side - 21%). There are much more small-leaved forests, shrubs and sparse forests on the Russian territory that testify about active economic use of the territory during

ing previous periods of mastering. Small - leaved forests were put into the category of natural objects of nature management since they are mainly matured and ripening forests now. Shrubs are often located in places of burns or occupy abandoned agricultural lands. Such areas are overgrown by shrubs for 4~7 years. Shrubs show relatively high share there, of which 21.4 % shows low economic activity and high share of the territory suffered from fires. Among recent fires one polygon on the Russian territory has been observed, similar places on the Chinese side have not been found. It is necessary to note that the forests after fires on the Chinese territory are rather quickly put in economic rotation being planted be saplings of coniferous and deciduous species. It is necessary to say that various reforestation measures are carried out on both sides of the border. A technique of clear cuttings of forests with subsequent planting of saplings of commercial tree species is applied on the Chinese territory. On the Russian territory, the technique of supporting natural reforestation is applied, when saplings of Korean pine are planted under cover of deciduous or broad - leaved forests. That explains rather big difference in parameter of "forest plantations". Unfortunately, such territories are difficult to determine by means of decoding of satel-

lite images.

No commercial loggings on the Russian part of the territory are carried out. At present most harvesting works take place in northern and central areas of the territory. Forests on the Chinese territory are an object of active industrial loggings. 210 polygons have been found on the area of 113.3 km². It is necessary to note that some part of the found polygons is not shown on the final map because of their insignificant size; however the quantity of such sites exceeds 90.

Arable lands occupy 30.1% on the Chinese territory, while only 4.1% on the Russian one. Quite often arable lands occupy slopes of Taipingling and its spurs. This kind of their distribution creates additional conditions for adverse ecological phenomena associated with soils erosion.

A coefficient of uniformity - heterogeneity of the territory was defined to precise a ratio of number and size of used lands within the territory under consideration. It equals 0.50 for the Chinese part of geosystem, and 0.9 for the Russian part. In other words, the Chinese part in greater degree defines a modern shape of economic use of the territory.

A map of current state (disturbance) of geosystem due to economic use has been drawn to assess a character of transformation of natural environment

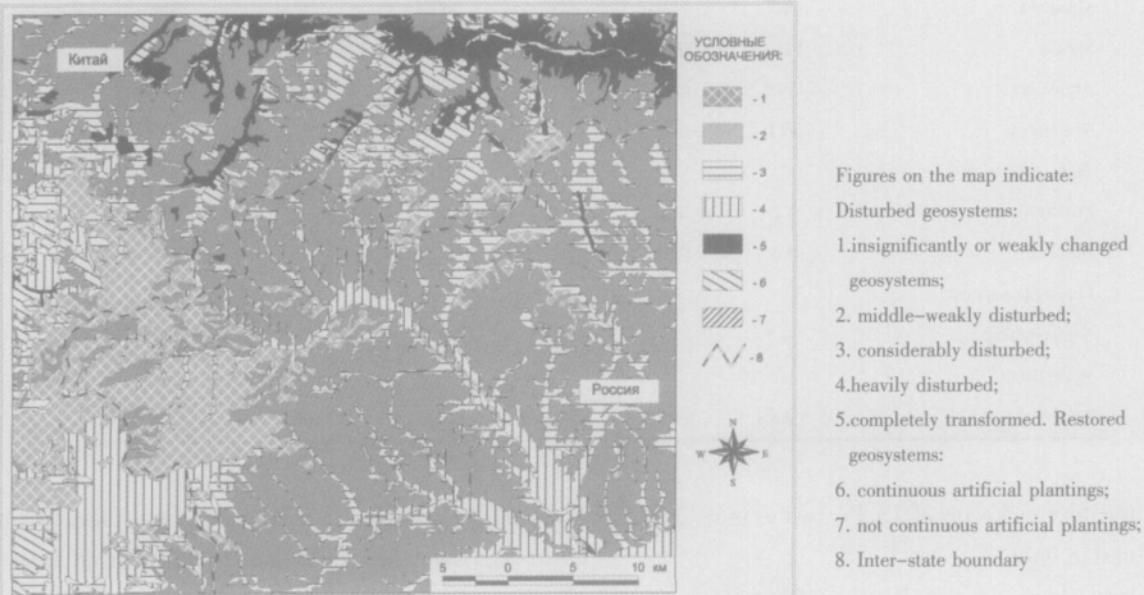


Fig.2 A fragment of a map of modern state of natural environment in peripheral zone of Khanakaiskaya transboundary territory

within the territory under consideration (Fig.2).

The methodic recommendations stated in a number of publications were used in the course of its drawing up. Qualitative estimations of geosystems' disturbance were obtained by experts way. Thus, coniferous and coniferous- deciduous geosystems are ranked to conditionally original and weakly disturbed; broad- leaved and deciduous - to middle weakly disturbed; small- leaved and shrubs - to middle heavily disturbed; sparse forests, meadows - to heavily disturbed. Arable lands, waste lands, forests cuttings, mining sites, water reservoirs and settlements have been ranked to anthropogenic or to completely transformed geosystems.

The circle of transboundary environmental problems has been defined for every type of disturbed lands. Thus, the main transboundary problem for insignificantly or weakly disturbed geosystems (coniferous and coniferous- deciduous geosystems) is pauperization of biodiversity; for middle disturbed (broad-leaved and deciduous) and heavily disturbed (sparse forests), meadows (on the spot of former cuttings and forest fires) - pauperization of biodiversity, violation of migratory ways of wild animals, their forage base, fragmentation of their habitats, increased fire danger; for heavily disturbed (small- leaved forests, shrubs, rivers and lakes) a high risk of flooding, transfer of

pollutants can be added to the above listed problems; for completely transformed (anthropogenic) geosystems - character transboundary environmental problems are pollution of surface waters, atmospheric transfer of polluting substances, destruction of habitats of wild animals, pauperization of biodiversity.

The restored geosystems (artificial plantings of different age) are separately defined. The main transboundary environmental problems of this type of geosystems have positive character and are asociated with improvement of biodiversity, migratory ways for wild animals, and their forage reserve. It is necessary to note that on the Russian territory weakly disturbed and middle disturbed lands occupy 49.3%, 34.4% on the Chinese side. Middle and heavily disturbed lands occupy 45.9% and 23.4% correspondingly. Completely transformed - 34.8% on the Chinese territory, and 4.8% - on the Russian side. Forest plantations occupy 7.4 % of the whole area in the Chinese part.

The map of current state of natural environment is supplemented with definition of qualitative characteristics of sensitivity of geosystems according to the features of their reaction to anthropogenic impacts (Tab.3).

"Sensitivity" here is understood as ability of natural component to change its properties and dynamic characteristics under influence of human economic

Tab.3 Sensitivity of geosystems to anthropogenic impact

Sensitivity degree	Sustainability	Type of geosystem
High	Unstable and extremely unstable	Near-topped and located in upper parts of valleys: coniferous forests, coniferous-deciduous, poly-dominant deciduous broad-leaved, small-leaved, sparse white birch forests, shrubs and meadows.
		Anthropogenic: fresh burns, wastelands, forest cuttings, mining sites, arable lands on steep slopes
Middle	Relatively unstable and relatively stable	Slope coniferous, coniferous-deciduous, polydominant deciduous, broad-leaved, small-leaved sparse forests, sparse forests, shrubs and meadows.
		Valley coniferous, coniferous-deciduous, polydominant deciduous, broad-leaved, small-leaved forests, sparse forests, shrubs and meadows.
Low	Stable	Anthropogenic geosystems: arable lands, forest plantations (open stands, artificial)
		Foothills and low hills: coniferous and coniferous-deciduous (artificial), polydominant deciduous, broad-leaved, small-leaved, sparse forests, shrubs, meadows.
		Plains: polydominant deciduous, small-leaved forests, sparse forests, shrubs and meadows.

activities. At that, the reaction of such components like ability of biotops to keep their natural qualities in result of various economic activities, sensitivity of geosystems to changing hydrological characteristics, features of reaction of morpholithogenic base of landscapes to anthropogenic impact, susceptibility of soils to water and wind erosion have been taken into account in this analysis.

Near-topped and located in the upper parts of valleys landscapes were ranked to high-sensitivity geosystems. In case of its economic use these landscapes are difficult to be restored that can lead to the essential reduction in biodiversity of flora and fauna, fragmentation of habitats. Their use often leads to changing dynamic stocks of moisture, water-regulating functions, occurrence and stirring up of erosive washout, gravitational processes. This category also include anthropogenic landscapes like burns, waste lands, forest cuttings, mining sites and arable lands on steep slopes. The slope (except for steep) and valley, and also anthropogenic landscapes - arable lands and forest plantations were ranked to middle-sensitive ones. These types of landscapes typically have rather quick restoration, both due to natural processes, and due to special economic measures. They play good drainage-regulating functions which are rather

quickly restored after various short-term economic impacts. Erosive and accumulative processes in river valleys proceed according to natural laws of river-beds deformation. Stirring up deflationary processes on arable lands, and slow mass displacement of substance on slopes are possible.

Landscapes of plains, foothills and low hills are referred to low sensitivity landscapes. They are leveled or weakly inclined surfaces, where processes of mass displacement of substances are not typical. The erosive phenomena are also not expressed, and soils are capable to keep natural structure and to function under influence of ongoing exogenic phenomena. The composition of biogeocenoses is rather quickly restored due to natural succession and reforestation measures.

To decrease an acuteness of transboundary environmental problems the following scheme of functional zoning of peripheral zone Khankaiskaya transboundary territory is offered (Fig.3).

It is offered to allocate 3 functional zones which include certain ecological zones. Residential areas, water reservoirs, and transport arteries requiring more detailed researches were excluded from the analysis.

The first functional zone - Conservation of especially valuable geosystems or transfers to this category

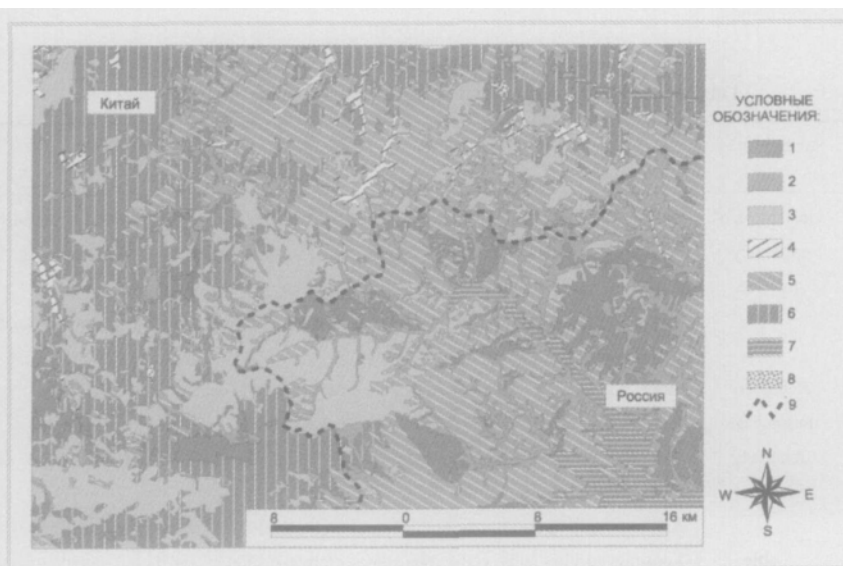


Fig.3 A fragment of the map of functional zoning of peripheral zone of Khankaiskaya transboundary territory according to the types of its economic use (landscape planning)

ry. Its main purpose is to conserve an environment-forming ecological framework of the territory, high-sensitivity landscapes of this zone provide (or can provide) a reproduction of natural resources and natural variety of coniferous-broadleaved forests. The first functional zone occupies 20.9% on the Chinese territory, and 19% on the Russian territory.

The second functional zone - Preferred improvement.

The main direction of activity in the fifth ecological zone is improvement with subsequent transfer to the category of extensive use. This functional zone occupies 54.8% on the Chinese territory, and 38.9 % on the Russian one.

The last one among defined functional zones is called to provide conservation of existing extensive use or transfer to this category. One ecological zone, the seventh one is included into it. This zone occupies 21.7% on the Chinese territory, and 41.5% on the Russian one.

Conclusion

The carried out analysis has shown a necessity of supplementing the technique of transboundary diagnostic analysis with characteristic of landscape structure of the territory under analysis, its modern economic use, disturbance as a result of economic activity, sensitivity of geosystems to anthropogenous burden. The results of these studies are realized in the map of functional zoning of the territory which offers scientifically proved measures on reduction of an acuteness of environmental problems, including transboundary environmental ones.

Such approach provides sustainable development of nature management within transboundary territories on principles of environmental safety of the countries.

Chemical pollution of Amur River, happened in result of accident in a chemical plant on the Chinese territory in the end of 2005, has caused a serious public resonance and has formed a basis for development of measures on reduction and prevention of water transboundary transfer of polluting substances be-

tween Russia and China.

Not less damage to deterioration of environmental situation within the Russian - Chinese transboundary territories is rendered by irrational economic activities which consequences are accumulating for long time. The environmental situation in many transboundary territories is close to critical. Therefore development of the joint program of ecologically sustainable nature management of transboundary territories is necessary on the basis of principles of landscape planning.

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跨国界地区地理系统景观功能分区 ——生态可持续的自然管理

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摘要: 在跨国边境地区的诊断分析中采用的对于环境问题进行分析的方法性的理论原则, 在许多方面决定了战略行动计划实现的效率。但是我们认为这种跨国边境地区的诊断分析方法应该包括环境和地理制图, 以及在陆地景观组织分析的基础上进行的功能性分区。边境地区可持续性自然管理的理论原则是用边界来保护自然资源的潜力或者甚至使之增长。因此景观功能分区会要求对边境区域内各种优先的、许可的和禁止的经济利用的分析。

保护性政治制度的确立、把资源管理与维护生态平衡的措施结合和阻止自然与人类的负反馈这 3 项景观优化原则具体的实现就是跨国边境地区景观功能分区地图, 这就是我们认为的边境地区诊断分析的主要目标。在分析陆地景观组织的基础上, 本文主要介绍边界地区景观功能分区诊断分析的方法(用于景观规划)。该方法在在中俄边境的 Pogranichny- taipailing 自然地理区域, 利用 Landsat- TM 图像进行试验和验证。

本文的研究表明对边境地区景观结构特征进行诊断分析是必要的, 分析包括它的现代经济利用方式、经济活动对景观的干扰、地理景观系统对人类活动压力的敏感性。研究结果通过绘制研究区景观分区地图得以体现, 地图科学地证明了举措对于减轻包括边界地区在内的区域环境问题具有一定的价值。

这样的方法提供了在保证国家环境安全的原则下, 对边境地区自然环境可持续性的管理。

关键词: 跨国界地区; 景观; 功能区; 诊断分析