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THE LANDSCAPE ECOLOGICAL ASSESSMENT AND PLANNING IN THE CONTROL WATERSHED BY RESERVOIR OF ERLONG MOUNTAIN

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ABSTRACT: Based on the theories of landscape ecology, landscape eco-environment in the control watershed by reservoir of Erlong Mountain in Heilongjiang Province was analyzed and assessed by using GIS technique and statistical model of Principal Component Analysis and Spatial Cluster Analysis. It is found that 100.08km^2 (6%) of the total area is in the state of kilter, 85.73km^2 (51%) of the total area is in the state of general, and 47.26km^2 (7%) and 15.48km^2 (6%) is in the relatively poor state and ideal state. According to landscape ecological structure, there are three landscape function areas being planned and designed. 1) Agricultural landscape function area: its developmental direction is tour agriculture and high-benefit agriculture. 2) Eco-environment protected function area: the direction of development and utilization of this region is to develop vigorously forest for soil and water conservation, and try to increase the rate of vegetation cover. 3) Forest landscape function area: rational cut and utilization of forest resources, space optimization disposal of category of forest, foster of forest and protection of wildwood will become the main development directions for this region. This study trys to provide scientific foundation for ecological restoration of the whole valley and its sustainable development.

KEY WORDS: landscape ecological assessment; landscape ecological planning; GIS

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1 INTRODUCTION

Landscape ecological analysis and assessment is the fundamental research content of landscape ecology. The result of landscape ecological assessment reflects many kinds of landscape ecological process and decides landscape space disposal form and combination (RUZICKA and MIKLOS, 1990), so landscape ecological assessment and research becomes one of indispensable research foundations of landscape ecological planning.

Landscape ecological planning emphasizes that the optimizing utilization of landscape should be suited and in harmony with the ecological condition. With maintaining healthy development of landscape ecology, we should put forward the project of how to rationally utilize resources through studying the influence of landscape structure on ecology processes, and on the basis of landscape analysis and comprehensive evaluation (WANG *et al.*, 1999).

In the reservoir region of Erlong Mountain, disturbance of human's activities has made healthy watershed ecosystem sharply degenerated and damaged: water loss and soil erosion, reservoir sedimentation, vegetation being destroyed, water quality deterioration and a series of ecological disasters, which made the health and integrality of watershed ecosystem face ever-larger damage. Therefore, this paper taking landscape ecology as the base of theories, supported by the geographic information system (GIS), through landscape structure analysis and landscape ecological comprehensive evaluation, makes optimal combinations of intrinsic landscape factors or introduces new elements, in order to adjust and establish new landscape structure to offer continuous live condition for all kinds of living.

2 STUDY AREA AND BACKGROUND

The watershed of reservoir of Erlong Mountain is located in 127°22′30″E – 127°37′30″E, 45°30′00″N –

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45°55′00″N, situated at Branch of Mt. Zhangguangcai in middle of Heilongjing Province, at south bank of the Songhua River, inside Bin County, to the east of Harbin at about 56km. The scope controlled by reservoir of Erlong Mountain is about 278.44km^2. The zone belongs to continental monsoon climate of cool temperature zone. In winter, the climate is dry and cold, because most of the time Siberia cold current controls it. In summer, it is warm and wet, for it is effected by ocean warm current air mass and Mongolia infrabar, with the maximum temperature of 36.1℃, and frozen time lasts for as long as over five months. The most soil category of the zone of Erlong Mountain is dark brown soil, dark soil and lessive. Vegetation belongs to floristic area of Changbai Mountains, sub-area of Zhangguangcai Mountain. Virgin forest is theropencedrymion, which give priority to Korean pine forest, but now it becomes crude secondary community because of long-term destruction. Reservoir of Erlong Mountain is a mesotype one which started to be built in 1958 and finished in 1968 with 94×10^6m^3 reservoir storage. The section of landscapes and interests with Erlong Mountain Reservoir as center has multinomial great functions such as flood-control, water supply and tourism, and all these functions are indispensable key factors for development of economy and society of Bin Country. But, owning to the effect of man-made and natural factors, the sustainable development of Erlong Mountain Reservoir has been threatened: 1) Natural ecological environment has been degenerated severely. The rate of vegetation cover has reduced to less than 50% from 75% at the beginning of founding new China in 1949. Most of the mountain body of upstream shallow mountainous area are nudity, erosion gully can be seen everywhere, water loss and soil erosion are badly serious. In reservoir area, because of not having functions of remaining water and evaporation, the follows have occurred: air drying and surface water reducing, soil sealing and unit production of crop falling. In order to complement output deficit, people enlarge acreage under cultivation at upland, which causes ecological vicious circle. 2) Silt of reservoir is very serious. In the 1960s, 1970s, 1980s and 1990s, the average anuual quantity of silt is 20.3×10^4m^3, 33.2×10^4m^3, 47.3×10^4m^3 and 77.9×10^4m^3. In 1994 silt carried by flood is 1/4 of the total quantity of silt, being 23% of flood storage capacity. The flood regulation function of Erlong Mountain Reservoir can only lasts for 15 years at depositional rate for the moment. 3) Water resources is short and water quality is deteriorated obviously. Because of the particularity of geological frame of Bin Country, the underground water resources is short. Erlong Mountain Reservoir is the only water-head of the citizen water-work that was built in the 1980s. So, Erlong Mountain Reservoir has already become the lifeline of citizen of Bin Country. But, because vegetation of collection area is destructed, a large quantity of silt enters reservoir and the ability of reservoir storage decreases, the contradictions between water-holding capacity and the demand of drinking water, industrial water and irrigation and so on gradually extruded. The problems for water often occur. The deterioration of water quality appears as turbidity being apparently raised, especially in main flood season. The turbidity of water quality not only rise at rate of hundred and hundred times, but also last very long. For example, the max turbidity reached 16 000 degree, (normal is about 20 degree), and lasted for four months with 2000 degree in super-flood in 1994. In addition, the eutrophication trend of water quality becomes very apparent. Because that large quantity of inorganic fertilizer has been used in the farmland of collection area, catering industry developed rapidly in the tour area and tourists become more and more, all of these made the eutrophication of water higher. If it cannot be controlled effectively, it would bring great adverse influence on the health of the residents in Bin Couny and the result is very severe. So it is the first problem to be solved for the people in Bin County to take precautions to save the reservoir and protect resource of water.

In general, the current and future of people of Bin County are closely linked to the recovery and sustainable development of ecological environment of Erlong Mountain and the whole zone. In order to orderly utilize the resource of this region, the only way is to jump out of the old mode of separate harnessing and nonstandard development, use science and technology as forerunner and start off with entire and comprehensive research and gradually establish sustainable development mechanism including optimistic disposal of resources, optimization of industrial structure and virtuous circle in ecosystem. Only in this way, can we really return upland to forest and recovery vegetation, preferably control silt and pollution and effectively protect water resources, in further realize the ideal of harmony development of human and environment, can the watershed of Erlong Monuntain Reservior take the way of sustainable development in harmony with its resources, environment, society and economy.

3 METHOD OF RESEARCH

Using the stock-map (1∶25 000), the land map (1∶25 000, Erlong Mountain Tree-farm of Bureau of

Forestry of Bin County, Heilongjiang Province, 1998) and existing land use map (1: 100 000, Burequ of Land Management of Bin County, Heilongjiang Province, 1998) in the platform which use software of ARC/INFO Geographic Information System, we make relative plots of zone of Erlong Mountain Reservoir digitized and input computer based on the open exploratory. We use cards of forest plot(the result of forest survey in 1998) supplied by Forest Bureau of Bin Country and SQL-server to found exterior Database, adopt loosening coupling geographic information system to select heterogeneity exponential indices and analyze landscape model.

3.1 Classification of Landscape Types

We divide the watershed into 10 landscape types in accordance with principle of comprehensive analysis and dominant factor and land use character (Fig. 1). They are: forest (f_1), inhabited area (f_2), water area (f_3), cultivated land (f_4), wasteland (f_5), land for preparation forest (f_6), immature forest (f_7), seed plot (f_8), useless area (f_9) and stump-land (f_{10}).

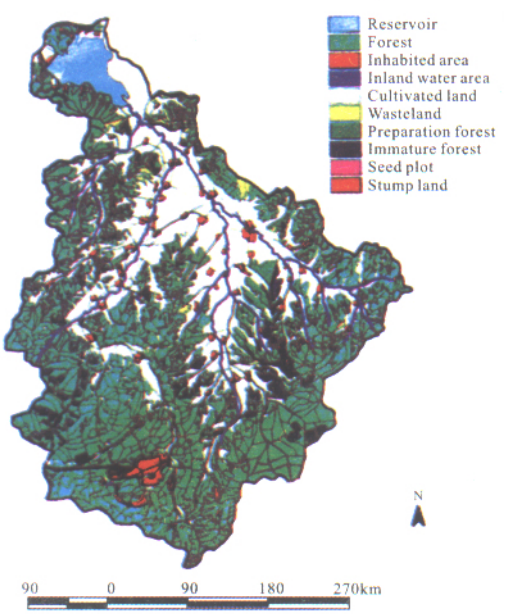

Fig. 1 Landscape types in the control watershed by Erlong Mountain Reservoir

3.2 Assessment and Analyses of Landscape Ecology

By analyzing the relation of surface feature, cover of vegetation and terrain, we select twelve factors and adopt principal components analytical method, ascertain four kinds of principal component of evaluating indicator of landscape ecology (Table 1, Table 2).

The fist kind: principal component of forest state (elevation, predominance tree species, canopy density, age of forest, category of forest etc).

The second kind: principal component of landscape type size (plot area, perimeter of plot etc.).

The third kind: principal component of water loss and soil erosion (soil kind, maximum slope of plot, soil level).

The fourth kind: principal component of degree of ecology recovery (forestation year, thickness of A_1 layer).

The result of the Principal Component Analysis in the procedure is that it can supply new start point which evaluates landscape ecological classification by further using space system clustering method. For GIS has the function of superposition in space we can make the result of analysis superposed with dominance and sensitive factor of ecology environment and get the assessment conclusion of landscape ecological classification.

4 ANALYSIS OF RESULT

4.1 Properties of Landscape Structure

This region has 2014 plots and 10 landscape types. The main landscape types are forest and farmland, their area amounts to 84.05% of the whole watershed area.

The landscape matrices of Erlong Mountain is forest, because the forest has the largest area (137.33km^2), fractal number(1.44) and adjacent landscape(nine types). The area explains the dominance of forest in wholle landscape, fractal number proclaims that forest shape is intricate, and the number embodys that forest controls the direction of matter and energy flow in the whole landscape.

We adopt landscape type area, ratio of landscape type, plot number, and ratio of plot, mean area of plots as indices to analyze(Table 3). The mean area of forest landscape plot is less than the area of whole landscape plot. From the ratio of plot area and plot number, we can see that the area of forest is 49.3%, but the ratio of plot number is 61.2%. Obviously, forest landscape plot has a high degree of dissevering and exhibit high degree fracture because of long-term man-made interference and continual logging. The area of cultivated land is 34.7% of whole watershed area, ratio of plot number is 16.09%, it has less degree of dissevering and its distribution is concentrated. The mean plot area of inhabited area is even smaller, the degree of fracture is

Table 1 Matrix of contribution rate of principal component

Factor	Principal component			
	1	2	3	4
Area	-0.182	0.827	0.120	0.256
Predominance tree species	0.688	0.295	3.685E-02	-0.266
Perimeter	-0.205	0.861	0.138	0.193
Aspect	-0.124	0.320	-0.314	0.377
Physiognomic type	-0.680	-0.213	0.554	0.319
Soil level	0.726	-3.847E-03	0.497	-0.113
Gradient	0.686	3.447E-02	0.562	-0.123
Canopy density	0.890	0.113	-0.281	-5.520E-02
Forestation year	0.329	-0.370	-0.240	0.572
Elevation	0.799	-5.857E-02	0.224	0.356
Age group	0.692	0.129	-0.198	8.827E-02
Thickness of A_1 layer	0.667	-0.209	0.111	0.499
Category of forest	0.917	0.128	-0.185	-0.129

Table 2 Rotation matrix of principal component

Factor	Principal component			
	1	2	3	4
Area	-3.636E-02	-1.387E-02	-0.112	0.885
Predominance tree species	0.650	0.447	-3.505E-02	9.128E-02
Perimeter	-3.356E-02	6.820E-04	-0.187	0.897
Aspect	5.568E-02	-0.379	0.202	0.413
Physiognomic type	-0.954	4.221E-02	1.071E-02	7.136E-02
Soil level	0.299	0.816	0.163	-7.282E-02
Gradient	0.249	0.852	0.121	-2.950E-02
Canopy density	0.852	0.249	0.310	-5.372E-02
Forestation year	8.926E-02	-0.131	0.756	-0.184
Elevation	0.340	0.548	0.634	1.710E-02
Age group	0.624	0.190	0.339	4.816E-02
Thickness of A_1 layer	0.217	0.356	0.756	-6.296E-02
Category of forest	0.847	0.355	0.245	-6.033E-02

Table 3 Area properties of landscape types in the watershed of Erlong Mountain Reservoir

Landscape types	Area of landscape (km^2)	Area percentage (%)	Number of plot	Number percentage (%)	Mean area of plot (km^2)
Forest(T_1)	137.3300	49.3212	1233	61.22	0.11137
Inhabited area(T_2)	8.4800	3.0455	135	6.70	0.06281
Water area(T_3)	9.990	3.5878	6	0.30	1.66500
Cultivated land(T_4)	96.7100	34.7328	324	16.09	0.29848
Wasteland(T_5)	3.9100	1.4043	69	3.43	0.05666
Preparation forest(T_6)	13.4900	4.8448	149	7.40	0.09053
Immature forest(T_7)	8.1800	2.9378	91	4.52	0.08989
Seed plot(T_8)	0.0200	0.0072	1	0.05	0.02000
Useless area(T_9)	0.0500	0.0180	2	0.10	0.02500
Stump-land(T_{10})	0.2800	0.1006	4	0.20	0.07000
Total	278.4400		2014		0.13825

even higher and its distribution is even more dispersive.

4.2 Landscape Ecological Classification and Evaluation

We compound-superpose space clustering analytic result table and sensitive factor of dominance ecological environment and can get the result of landscape ecological classification assessment with the space-superposition analyze function of GIS (Table 4, Fig. 2).

4.3 Design and Planning of Landscape Ecological Structure

In accordance with Erlong Mountain region land-

Table 4 Eco-landscape assessment properties in the watershed of Erlong Mountain Reservoir

Eco-landscape assessment	Area (km^2)	Properties
Ideal condition	45.48	Ecological environment is not disturbed and destructed. Ecosystem structure is integrity. The function is the strongest. The key landscape is forest.
Good condition	100.08	Ecological environment is not disturbed and destructed. Ecosystem structure is also integrity. The function is stronger. The key landscape is forest.
General condition	85.73	Ecological environment is subjected to some destruction. Ecosystem tenable fundamental function can be retrieved, if only subjected to general interference. The key landscape is agriculture landscape.
Bad condition	47.16	Ecological environment is subjected to large destruction. Ecosystem structure has great change. Function is depressed and difficult to recovery after damaged. The key landscape is degeneration of nature ecology (water loss and soil erosion, urbanization course and so on).

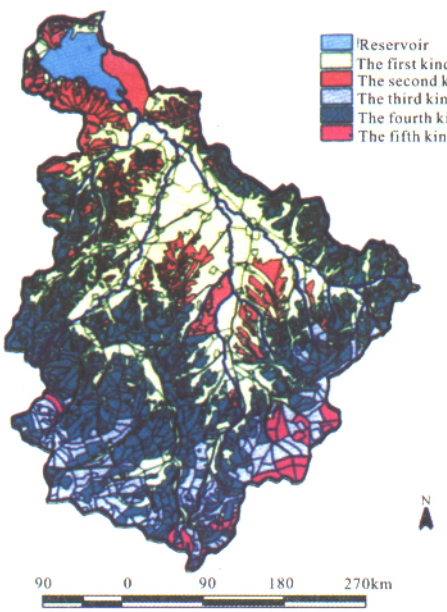

Fig. 2 Principal componential types of eco-landscape in the control watershed by Erlong Mountain Reservoir

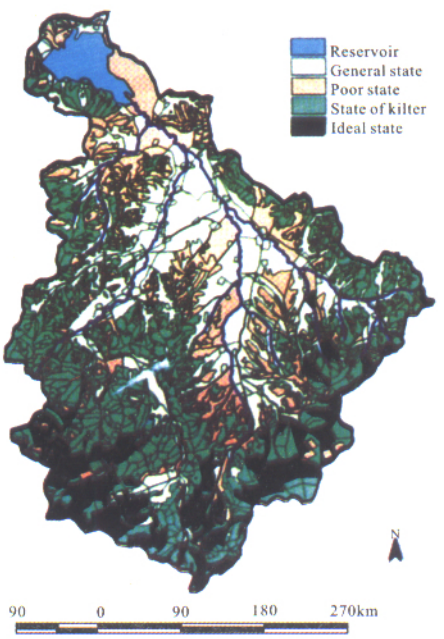

Fig. 3 Eco-landscape planning in the control watershed by Erlong Mountain Reservoir

scape type and landscape ecological evaluation map (1: 25 000), we can see landscape space structure of this zone appears as three layers structure: agriculture-degeneration of ecological environment-forest. Inner layer gives priority to agriculture tilth landscape; middle layer gives priority to landscape of nature ecological environment degeneration (water loss and soil erosion, scarp reclamation, climate dryness and so on); outer layer is forest landscape, which has a favorable ecological environment (Fig. 3).

4.3.1 Region of agriculture landscape domain

The domain, in inner layer of the watershed, both sides of the Fei River and the Duzui River, is 31% of total area and its control-area is 85.73km^2. Landscape course of this domain gives priority to agriculture which compromises manifold benefits of economy, ecology, society, tour agriculture and high-benefit agriculture. It can control construction acreage of city and county, especially the outspread of rural settlement, perfect road and irrigation in order to improve geometrical association between landscapes, extend and perfect hedge system in order to give full play to function of holding back sandstorm.

4.3.2 Region of ecological environment protection domain

The domain, being in bad ecological environment condition, lies in the middle layer of the watershed and constitutes 17% of total area. Its control-area is 47.2km^2. Water loss and soil erosion, vegetation cover reduction, etc. are the main landscape courses. This domain carries out the protection function of ecological environment. The direction of development and utilization of this region is to develop vigorously forest for soil and water

conservation, and try to increase the rate of vegetation cover. The recovery and harness are shown as follows:

(1) Hillside cultivated land is the section of severe soil erosion in this domain, which constitutes 11.8% of total area. These cultivated land has big gradient, and lacks of essential measures of water and soil conservation. The unit area output is very low. Keeping on plowing cannot sharply increase the output of crop, instead it can even aggravate water loss and soil erosion. We should return farm land into forest or grassland (Table 3). We can give priority to plantation at good condition of site but we should plant grass first on slope to make preparation for forestation in future at bad condition of site.

(2) Hill and mound is the main grain producing area of the watershed. The soil erosion is more serious but we shouldn't simply return farm land into grassland, otherwise the food balance of supply and demand in the region would be badly influenced. The only way is to adopt certain water-and-soil conservation measures to control it. At present, the comparative maturity ways are to found isolated area, to select species of trees which grow fast and have diversified economy worth in this land, to form live fence, to set up agriculture and forestry compound system. If we can do as so, we cannot only effectively protect erosion, but also compensate the loss caused by reducing cultivated land with economy trees in isolated area. We can build terrace to decrease the cultivated land gradient at the region whose gradient is too great to found isolated area. Of course, in this way we need use substantive manpower and material resources.

(3) As for the secondary forest that had been severely damaged it should be noted to join arbor, frutex and grass together while recovering vegetation by planting trees in order to build a favorable vegetation structure.

4.3.3 Region of forest landscape domain

The domain, whose ecological environment is in good and ideal condition, lies in outer layer of the watershed and constitutes 52% of total area. Its controlling area is 115.56 km^2, in which the area in ideal condition is 16% of total area.

From predominance tree species, age of tree structure, forest canopy density, spatial distribution information supplied by plot, we can see that broad leaf mix secondary forest dominates in the region, a small quantity of larch and other conifers also inlays in this region. The area of forest whose total canopy density is above 0.7 accounts for 24.56km^2, which constitutes 19% of total area. The age of forest is mainly stand of sapling(63.3km^2) and middle age forest(62.44km^2), which constitute 91%. The near matured and over-matured forest are less, just for 9%. Irrationality of age of tree structure explains that available forest resources is less at present, at the same time, it shows the significance and arduous of resources protection. So, rational cutting and utilization of forest resources, space optimization disposal of forest species, foster of forest and protection of wildwood will become the main development directions for this region.

5 CONCLUSION

It has great important guidance significance to the recovery of ecological environment and sustainable development in the study region to portray landscape ecological environment quantitatively and orientationally by technologies of geographic information system(GIS). It can supply scientific foundation for establishing a sustainable development ecosystem of the whole watershed.

Planning and design of landscape ecology is the applied direction of landscape ecology combining with practice and the spatial way to realize sustainable development of the region (KUHNEN, 1992). Landscape ecology planning is essentially different to the old single target planning. The most difference is that the landscape ecological planning regards landscape as resources and deal with it integrally, and connecting human demand with the natural characters and process, and pay main attention to the resources allocation in terms of macro scale (WANG and HAN, 2000). The landscape planning of Erlong Mountain Reservoir not only concentrates its attention on short-term demand of human, but also place more emphasizes upon the ecological value of landscape as an intricate living tissue integral and its long-term benefit for human.

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