GIS Based Evaluation System for Ecological Constraints of Dianchi Lake Basin

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Abstract With the advance of urbanization process and rapid growth of urban population, the construction land scale in Dianchi Lake basin increases at a sharp speed. Due to lack of reasonable scale control and space optimization, many areas have the problem of blind growth in construction land. On the one hand, it results in deterioration of regional ecological environment. On the other, it poses hidden danger for sustainable land use in the basin. Therefore, in order to coordination of regional land use and ecological environment construction, this paper on the basis of the existing various zoning method, the natural ecological conditions and resources environment as the constraint conditions of regional ecological balance, puts forward the Dianchi lake watershed ecological constraint type classification method based on GIS, and discusses the evaluation unit division, index selection and handling technical issues. Through evaluating ecological constraints of Dianchi Lake basin, this study divided Dianchi Lake basin into extremely high, higher, high, medium and low ecological constraint zones. Finally, it came up with guiding and regulating measures for land use of each type of ecological constraint, in the hope of providing scientific basis for optimum allocation of land resources in Dianchi Lake basin.

Key words Dianchi Lake basin, Ecological protection, GIS, Evaluation of ecological constraints

Economic development leads to expansion of construction land. In the disorderly development of land, occupation of quality farmland occurs now and then. As a result, landless farmers grow in large numbers and social stability is seriously threatened. In addition, the area of quality farmland around towns is decreasing and the quality is reducing. This leads to deterioration of land ecological environment and aggravates water loss and soil erosion. This worsens degradation of regional ecological environment.

Dianchi Lake basin is plateau lakeside ecosystem typical of Yunnan Province. In this ecosystem, mountain, basin, and lake are major parts. All matters flow from high to flow areas, namely, from mountain to lake. Thus, lake becomes the end point of damage resulted from improper land use. Dianchi Lake basin is the central social, economic and population regions of Yunnan Province. For a long time, all aspects of Dianchi Lake basin take on prosperous trend. At the same time, serious water pollution of Dianchi Lake becomes an underestimated problem. With rapid growth of economy, much vegetation in Dianchi Lake basin is destroyed, farmland is occupied, water is polluted, and regional ecological balance is faced with serious challenge. The control of Dianchi Lake should not stay in surrounding areas. Instead, it is required to consider ecological conditions from entire range of Dianchi Lake basin, and conduct spatial regulation and industrial guiding of construction land, to realize integrity of Dianchi Lake control.

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1 Overview of study area

Dianchi Lake basin is situated in the central area of Yunnan - Guizhou Plateau and the watershed of Changjiang River, Zhujiang River and Red River, covering Wuhua District, Panlong District, Xishan District, Guandu District, and Chenggong District of Kunming City and parts of Jinning County and Songming County. The geographical coordinate is 102°29′E - 103°01′E, and 24°29′N - 25°28′N. Through calculation after image registration, the basin has an area of 2871.52 km^2. The entire basin is long from south to north and narrow from east to west. And the terrain includes mountains, wash plain, and Dianchi Lake water area.

2 Study methods and steps

2.1 Data collection and digitalization Prior to evaluation, it is required to analyze data and map necessary for evaluation system and take pertinent data collection. Then, using graphics processing function of Arc-GIS, we took digitalized processing of collected data, and preliminarily set up the basic database for evaluation of Dianchi Lake basin ecological constraint.

2.2 Selection of evaluation factors In all collected data and materials, it is required to select ecological factors according to feature and development characteristic of evaluation area. Generally, this can be carried out using Delphi method and survey and analysis method. For different areas, evaluation factors are different. In line with different analysis objects and application purposes, number and weight value of factors selected for ecological constraint evaluation are not the same.

2.3 Determination of indicator weight After evaluation factors are selected, it is possible to adopt Delphi method or analytic hierarchy process (AHP) to determine indicator weight of evalua-

tion factors.

2.4 Single factor evaluation In geographical information system (GIS), each evaluation factor can be taken as a layer separately. Using ArcGIS, we divided each layer into uniform grid size, and scored all grids of each layer according to evaluation criteria of each evaluation factor. Then, we obtained the hierarchical chart for single factor ecological constraint evaluation.

2.5 Comprehensive evaluation In the evaluation system, it is required to assign different weight for each evaluation factor, to indicate importance of evaluation factor. Generally, Delphi method or analytic hierarchy process (AHP) are used to determine weight of evaluation factors. Using ArcGIS, we carried out superposition analysis of layers of each evaluation factors, and calculated the weighted sum of each grid, to obtain comprehensive score of multiple factors in each grid. Finally, we conducted superposition analysis of multiple factors and obtained final layer input, i. e. the final evaluation result chart.

3 Establishment of evaluation system

3.1 Dividing evaluation units The purpose of dividing evaluation units is to facilitate calculation and expression, to fully reflect regional difference of urban land use quality. Generally, this is the first step of land evaluation. Features of units are not completely uniform and there are great differences between units. The division of GIS ecological constraint evaluation units is completed in the generation process of single factor suitability layer. Through converting vector to grid, the size of evaluation unit was determined as 50 x 50 grid.

3.2 Selection of evaluation factors According to actual conditions of Dianchi Lake basin, we firstly selected special factors in accordance with one – ballot veto principle. In other words, occurrence of these factors will be directly classified as extremely high ecological constraint zone where it is not suitable for construction and high ecological protection should be taken, to maintain ecological balance and land functions. After selecting special factors, we selected general factors to evaluate ecological constraints in rest regions, and divided higher, high, medium and low ecological constraint zones.

3.2.1 Special factors.

(1) Capital farmland protection zone. According to *Regulations on Protection of Capital Farmland* (No. 257 document of State Council, issued on December 27, 1998), capital farmland refers to cultivated land that should not be occupied for a long term in overall planning of land use on the basis of prediction about demands of agricultural products and construction land according to population and socio – economic development in certain period. As per Article 15 of Section 3 of *Regulations on Protection of Capital Farmland*, once the protection zone of capital farmland is designated legally, no entity or individual may change or occupy. This shows protection effort of the state, but it is still necessary to enhance farmland ecological protection and control, and maintain its productivity.

(2) Source area of drinking water. This includes water source areas for urban resident living and public service water (such as government bodies, enterprises and institutions, hospitals, schools, catering industry, and tourism industry), including rivers, lakes, reservoirs, and ground water. Major protection zones include three levels for water source areas of drinking water in Kunming City. The first level protection zone should meet hygienic requirements for drinking water. The first level protection zones of water source areas in Kunming City mainly include Yunlong Reservoir, Songhua Dam, Dahe River, Chaihe River, Baoxiang River, Hongpo Reservoir and Ziwei Village Reservoir. According to requirements of Working Scheme for Drinking Water Source Area Protection Action of Kunming City, the protection zones of water source areas should build three lines of defense " ecological rehabilitation, ecological control, and ecological protection", and the first level protection zone should built ecological shelter forest.

(3) Dianchi Lake wetland. Wetland is the transition zone of land system and open water ecological system. With powerful ecological cleaning function, wetland plays an extremely important role in ecological balance. It not only has rich resources, but also has great environmental adjusting function and huge ecological benefit. In storing water, adjusting river run-off, supplying ground water, and maintaining regional water balance, wetland plays an important role and is a natural "sponge" of water storage and flood prevention. In the world, many countries attach importance to wetland. For example, United Kingdom transformed the old waste industrial park 25 minutes away from the Buckingham Palace, to London wetland center, which is the first wetland built in metropolis. In addition, Hyoko Lake conservation wetland and Lake Biwa wetland park of Japan and Asan wetland experimental school of South Korea are all excellent wetland protection examples.

(4) Dianchi Lake basin first level protection zone. Regulations on Protection of Dianchi Lake Basin designate protection areas of Dianchi Lake basin. It includes the first, second and third level protection zones and urban drinking water source protection zone. The first level protection zone is the area from protection boundary marker horizontally extending 100 m. In the Regulations, Article 12 specifies that it is required to organize and implement ecological rehabilitation, build and protect ecological wetland, and ecological forest within the first level protection zone; Article 34 specifies that it is prohibited to build, reconstruct and expand buildings and structures in within the first level protection zone.

3.2.2 General factors.

(1) Current situations of land use. Current situations of land use can comprehensively reflect land use types and spatial distribution, and can really reflect factors of ground ecological environment types. For classification of land use, there are two different periods: one is the classification of Second National Land Survey, and the other is classification of land use plan. The first one classifies land use into 2 levels, and the second one classifies it into 3

levels. Many scholars take current land use situation as an essential factor. For example, Huang Xiaoyan took land use as an evaluation factor in the ecological suitability study based on regional land development carried out in Jiulongpo District of Chongqing Municipality, and classified land use into four types, namely, forest, water, farmland and others, with decreasing suitability level.

In this study, for current land use situation, we mainly evaluated land types closely correlated with ecological constraints, and classified land within Dianchi Lake basin into 7 types, namely, water land, forest land (including coniferous forest, broad – leaf forest and mixed forest), grassland, farmland, garden land, construction land, and other unused land.

(2) Slope. Slope directly influences soil erosion and land use, and consequently affects land ecosystem stability and ecological suitability, so it is the most important indicator reflecting stability or vulnerability of land ecological environment. Plant growth has certain selection for slope. Generally, shrubs or small arbors can grow only in areas with slope larger than 25 degrees. In areas with slope larger than 45 degrees, it is difficult to grow, even for turfs. In China's urban plan, for different types of construction land, the planned suitable slope is different. In the Code for Vertical Planning on Urban Field issued by Ministry of Construction, it specifies that the largest slope suitable for various types of construction land is 25 degrees. In the Second National Land Survey, it divides slope into 5 levels: 0° – 2°, 2° – 6°, 6° – 15°, 15° – 25° and above 25°. Since Yunnan Province is a plateau mountainous province with small dam areas but large mountainous areas, we divided slope of hilly areas of Yunnan Province into five levels, namely, 0° – 8°, 8° – 5°, 15° – 25°, 25° – 35° and above 35°.

(3) Main reservoirs in the basin. Reservoirs are key areas needing ecological protection. To strengthen protection of major reservoirs and facilities thereof in Kunming City, bring into play functions of reservoir, prevent water pollution, and ensure safety of drinking water, it is required to take ecological protection of major reservoirs in Kunming City, to guarantee efficient supply of water resources in downtown of Kunming City.

(4) Water loss and soil erosion. As an important indicator reflecting ecological balance, water loss and soil erosion is mainly resulted from serious damage of plant in humid and semi – humid areas. It is greatly detrimental to local ecological environment, production, living and economic development. Water loss and soil erosion will damage ground intactness, reduce soil fertility, result in soil hardening and desertification, influence agricultural production, threaten urban safety, and worsen occurrence and development of natural disasters. Therefore, it is necessary to consider the water loss and soil erosion factor in the evaluation of ecological constraints in Dianchi Lake basin.

(5) Geological disasters. Geological disaster is a major natural factor threatening safety of urban buildings. In areas subject to geological disasters, the cost for disaster prevention is high, and buildings have high safety risk, thus it needs much ecological maintenance to keep regional ecological balance. Areas with strong growth of adverse geological phenomenon and areas with strong dynamic geological action will exert great influence on urban construction, and often create dangers.

(6) Vegetation coverage. The vegetation coverage is an essential factor for assessing regional ecological environment. In areas with higher vegetation coverage, ecological environment generally remains in balance state, and plant grows well, so it is able to effectively increase water storage capacity of soil, stabilize soil, effectively reduce occurrence of such geological disaster as collapse, mud-rock flow, and landslide, and reduce hidden dangers generated from geological disasters to a great extent.

3.3 Determination of indicator weight In this study, we selected special factors in accordance with one – ballot veto principle, and directly classified areas with these factors as extremely high ecological constraint zone, then conducted the ecological constraint evaluation for general factors. According to influence of factors on regional ecological environment, we divided evaluation factors into several ecological suitability levels (listed in Table 1).

Table 1 Classification criteria and weight of factors for evaluating ecological constraints in Dianchi Lake basin

Evaluation factors		Evaluation criteria	Point	Weight
Special factors	Capital farmland protection zone	One – ballot veto		
	Source area of drinking water			
	Dianchi Lake wetland			
	Dianchi Lake basin first level protection zone			
	Current situations of land use	Other unused land	1	0.24
		Construction land	2	
		Waste grassland	3	
		Farmland	4	
		Garden land	5	
		Coniferous forest	6	
		Mixed forest	7	
		Broad – leaf forest	8	
		Water land	9	
General factors	Slope	Above 35°	1	0.2
		25° – 35°	3	
		15° – 25°	5	
		8° – 15°	7	

(Table 1)

Evaluation factors	Evaluation criteria	Point	Weight
	0° – 8°	9	
Main reservoirs in the basin	Other areas	1	0.14
	Reservoir buffer 1500 m	3	
	Reservoir buffer 1000m	5	
	Reservoir buffer 500m	7	
	Reservoir buffer 50m	9	
Water loss and soil erosion	Slight erosion	1	0.13
	General erosion	5	
	Medium erosion	9	
Geological disasters	Other areas	1	0.11
	Disaster point buffer 2000 m	3	
	Disaster point buffer 1500m	5	
	Disaster point buffer 1000m	7	
	Disaster point buffer 500m	9	
Vegetation coverage	0.7 – 1	1	0.18
	0.5 – 0.7	3	
	0.3 – 0.5	5	
	0.15 – 0.3	7	
	≤0.15	9	

We adopted Delphi method to determine weight of evaluation factors. In this process, it is necessary to select experts of different disciplines to discuss. Therefore, we found 15 experts specialized in land use, ecology and geological disasters from Yunnan Province, and finally determined weight of each indicator through expert voting for three times.

3.4 Evaluation results According to classification of factors in Table 1, we carried out single factor evaluation for special factors and general factors separately with the aid of spatial analysis tool of ArcGIS9.3. Comparing evaluation results of special factors with general factors, areas with special factors are extremely high ecological constraint areas. Deducting the basin beyond these areas, according to evaluation results of general factors, we classified higher, high, medium and low ecological constraint zones, and finally obtained division results of ecological constraint zones in Dianchi Lake basin.

Table 2 Results of Ecological constraint zones in Dianchi Lake basin

Ecological constraint zones	Area km^2	Percentage %
Low ecological constraint zone	76.42	2.66
Medium ecological constraint zone	1189.25	41.42
High ecological constraint zone	713.47	24.85
Higher ecological constraint zone	212.24	7.39
Extremely high ecological constraint zone	383.24	13.35
Dianchi Lake water area	296.9	10.34
Total	2871.52	100.00

4 Conclusions

The distribution of 5 types of ecological constraint zones is relatively separate in Dianchi Lake basin. Except 296.9 km^2, Dianchi Lake basin has 2574.62 km^2 ecological constraint zones. The extremely high ecological constraint zone, covering an area of 383.24km^2 (accounting for 13.35%), is mainly distributed in Songming County and Jinning County, and is capital farmland protection zone and drinking water source area in the evaluation system. Higher ecological constraint zone, covering an area of 212.24 km^2 (accounting for 7.39%), is mainly distributed in Wuhua District, Chenggong District and Jinning County, where there are major reservoirs, areas subject to geological disasters, and construction land and used land with slope above 25°. The high ecological constraint zone, covering an area of 713.47 km^2 (accounting for 24.85%), has distribution in all counties, including slight water loss and soil erosion areas, and construction land and used land with slope below 25°. The medium ecological constraint zone, covering an area of 1189.25 km^2 (accounting for 41.42%), has large distribution in all counties, mainly various types of land with slope below 25°. The construction land with vegetation coverage lower than 15% in downtown is mainly distributed in this zone.

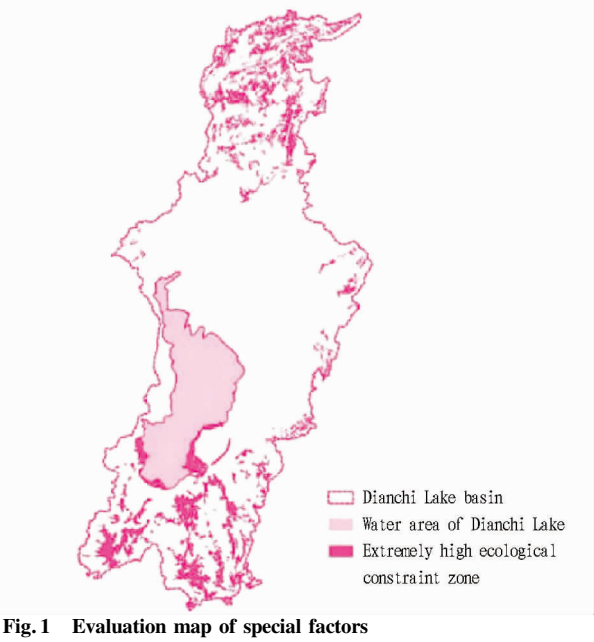

Fig.1 Evaluation map of special factors

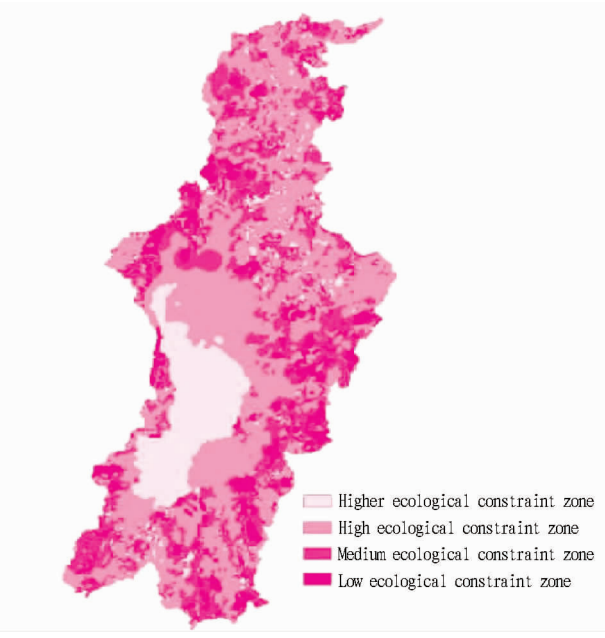

Fig. 2 Evaluation map of general factors

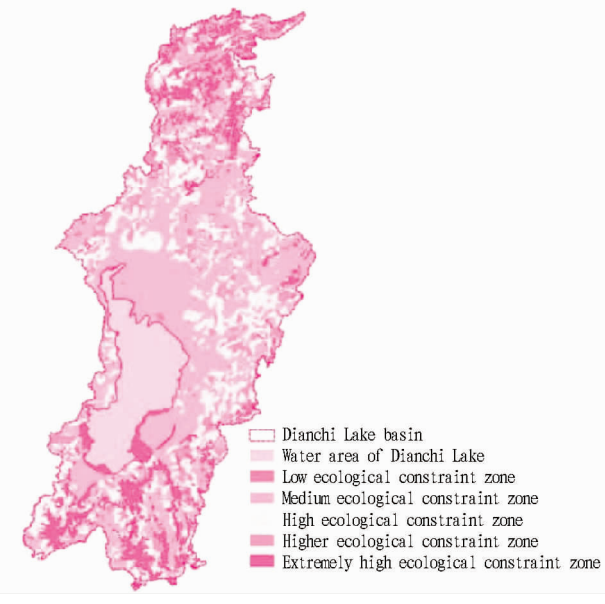

Fig. 3 Ecological constraint zones in Dianchi Lake basin

The low ecological constraint zone, covering an area of 76.42 km^2 (accounting for 2.66%), has small distribution in all counties, mainly water land, forest land and waste grassland with slope below 8°.

5 Discussion of zoning and policy recommendations

In land use pattern of plateau lake areas, expansion of urban village construction land is correlated with lake water environment, thus it is required to leave adequate ecological land and green space for lake shore, control land use scale for urban village construction. Only through conserving land use and maintaining benign cycle of ecosystem of the lake basin, may it be able to guarantee coordination of economic development and urbanization of plateau lake areas with ecological protection. On this basis, with the principle of ecology priority as guidance, it is required to consider whether the land is suitable for development and construction, and also pay attention to degree of ecological constraints. Both points should be considered together and analyzed comprehensively.

5.1 Extremely high ecological constraint zone The extremely high ecological constraint zone mainly includes capital farmland protection zone, drinking water source area protection zone, Dianchi Lake and Dianchi Lake basin first level protection zone. This zone has powerful ecological functions and plays an important function in keeping ecological balance and maintaining its benign development. Once ecological balance of this zone is destroyed, it is difficult to restore in short time. Therefore, it is forbidden to any urban construction and development in this zone. Instead, this zone may be developed to ecological protection zone, to strictly protect regional natural and ecological environment, and improve diversity and stability of regional ecosystem.

5.2 Higher ecological constraint zone For this zone, it is required to strengthen ecological and environmental protection and control, so as to assist in maintaining ecological balance of extremely high ecological constraint zone. Besides, it should follow the principle of protection priority, avoid and reduce new construction land as much as possible, increase intense use of construction land in this zone, bring into full play land use efficiency, and keep and improve ecological environmental quality of this zone.

5.3 High ecological constraint zone In this zone, the natural ecological constraint is still very high. It is recommended to strengthen ecological construction, not conduct construction activity detrimental to ecological environment. For example, it is possible to optimize and adjust land use structure in this zone, reduce industrial land and urban construction land, firstly consider farmland distribution, promote intensive development of regional agriculture, and increase regional grain productivity.

5.4 Medium ecological constraint zone This zone has certain natural foundation, thus regional construction and development should follow the principle of "farming if suitable for farmland, forestry if suitable for forest, and building if suitable for construction". Specifically, areas with high soil fertility and abundant water source can be developed to farmland; areas with high slope and far to towns may be developed to forest land; and flat areas with excellent location advantage may be developed to construction land. However, before development and construction, ecological protection measures must be taken. In addition, strict control should be taken over intensity and development mode of construction actions. It is strictly prohibited to take activities detrimental to ecological environment, to avoid damage of ecological environment.

5.5 Low ecological constraint zone In this zone, regional ecosystem has high stability, resource and environment carrying

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But in the survey of pesticide residue problem, only 44% of farmers think that is a serious problem, more than half of farmers do not have a clear understanding for the harm of pesticide residues. 70% of farmers think protecting rural ecological environment has a promoting effect on agricultural production activities, this fully shows that more and more farmers gradually realize the importance of environmental protection work to themselves and future generations' development.

4 Conclusions

This investigation and study choose rural areas of five counties from Chongqing city and Zhejiang province as our samples, our investigation and statistical analysis includes the following four aspects: farmers' cognition on non-point source pollution concept, farmers' cognition to rural environment satisfaction, farmers' cognition on non-point source pollution in agricultural production and farmers' cognition on the consequences of agricultural non-point source pollution and the effects on ecological environment.

Overall, the cognition of farmers in China's western region about agricultural non-point source pollution is still at a lower level, it is related in their cultural level of education; relative to the west, the statistical results of samples from Wenzhou region show that the southeast region of farmers in economic development level is higher, in a higher level economic development area, with high cultural quality, and more opportunity to contact with modern urban culture, farmers of southeast have higher ideological awareness in the aspect of environmental protection consciousness. The analysis and conclusions of the consciousness cognition on agricultural non-point source pollution, provide the support in theory and practice for optimizing farmers' behavior, promoting the management of agricultural non-point source pollution and implementing new rural construction goal.

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capacity is strong, the ability of enduring external disturbance is high, and urban development and construction activities have little influence and the ecological constraint is low. Therefore, it is suitable to conduct large scale urban construction and industrial development, and develop this zone into economic center of Dianchi Lake basin. In future, it is recommended to speed up urban development, boost infrastructure construction, make industrial distribution more reasonable, promote development of industrial clusters, increase efficiency and intensification of land resource, and drive the process of urbanization.

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