ANALYSIS ON LANDSCAPE PATTERN OF LAND USE AND ECO-ENVIRONMENT CHARACTERISTICS OF THREE LAKE BASINS IN YUNNAN PROVINCE, CHINA

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Abstract. Lake Basin pollution has become an important environmental problem, exploring its landscape pattern of land use and eco-environment characteristics is of great significance for environmental pollution control. Through the analysis of the landscape pattern indices of diversity, evenness, dominance and fragmentation of the three lake basins in Yunnan province of China, and based on the evaluation results of the ecological environment of the lake basins, to explore the relationship and characteristics between the landscape pattern of land use and its ecological environment. Research indicates: (1) According to the analysis of landscape pattern of land use in the basin, the level of landscape diversity and evenness in the Fuxian Lake Basin is the highest, followed by the Erhai Basin. However, the lowest is in the Dianchi Basin; the degree of landscape fragmentation in the Dianchi Basin is the highest, followed by the Fuxian Lake Basin, and the lowest in the Erhai Basin. (2) According to the results of the ecological environmental quality assessment, Dianchi Basin is the worst, while the Erhai Basin and Fuxian Lake Basin are better, and the Fuxian Lake Basin is the best. (3) The landscape pattern of land use in the basin is closely related to the quality of the ecological environment. Basins with good ecological environment quality have a relatively high degree of diversity and evenness, and relatively low fragmentation; in the basins with poor ecological environment, the degree of evenness and diversity of landscape are relatively low, and the degree of landscape fragmentation is relatively high.
Keywords: *plateau lake basin, remote sensing interpretation, land use; landscape pattern index, ecological environment evaluation*

Introduction

Along with the rapid development of social economy and urbanization process accelerated, environmental quality is declining, population is increasing and the environmental problems are increasingly prominent, the land use / cover change and ecological environment research have become a hot topic in the world. The research content mainly includes the land use change rule (Rao, 2015; Yang, 2016; Sharma, 2017; Kumar, 2017), mechanism (Zhang, 2012; Fu, 2012; Martyn et al., 2017), driving force (Li, 2014; Cattarino, 2014; Chai, 2016; Yuan, 2016; Wenban-Smith, 2017), landscape spatial pattern and so on (Xu, 2012; Yu, 2016; Liu, 2015; Lamine, 2018), the research on landscape pattern of land use mainly in provincial (Li, 2005; Zhang, 2009), municipal (country) regions (Ge, 2016; Wang, 2015; Hassan, 2017), a typical river basin (Feng, 2010; Chen, 2009; Mehrian, 2016) as the scale, abundant research results have been achieved. In the above studies, the longitudinal analysis of different phases in the same region is the main research, and the landscape pattern of land use and ecological

environment were often studied separately, and the research on the relationship and characteristics between landscape pattern of land use and ecological environment in different lake basins was relatively insufficient.

According to "The Environmental Status Bulletin of Yunnan Province in 2015" (Yunnan Environmental Protection Department, 2016), the water quality of Lugu Lake Basin and Fuxian Lake Basin in the nine great plateau lake basins of Yunnan Province in China was excellent, the water quality in the Erhai Basin was good, and the Dianchi Basin was heavily polluted, and land use is closely related to lake pollution. This study selected the Dianchi Basin, Erhai Basin and Fuxian Lake Basin as the research object, the relationship and characteristics between landscape pattern of land use and ecological environment in the three major lake basins were analyzed, which is of great significance for optimizing landscape structure of land use and controlling lake water environment pollution.

Materials and methods

General background of the study area

In order to study the relevance and comparability, this article referred to the two major factors of socio-economic development level and lake pollution degree. The Dianchi Basin (capital of the provincial capital, heavy pollution), the Erhai Basin (prefecture-level city, good water quality) and the Fuxian Lake Basin (County Town, Type I Water Quality) are selected as the research area to explore the characteristics of land use landscape and ecological environment quality in the three major lake basins (*Fig. 1*).

The total area of the Dianchi Basin is 2891.07 km^2. The entire basin's terrain gradually decreased from north to south. With the rapid development of social economy, the rapid expansion of urban built-up areas in Kunming, the landscape pattern of land use in the lake basin has undergone major changes, and the landscape has presented a trend of fragmentation and the development of complex boundaries (Zhang, 2013).

The total area of the Erhai Basin is about 2609.07 km^2, which is second only to Dianchi Basin in the plateau lakes of Yunnan Province. The area along the lake is flat and the periphery is dominated by mountains. The type of land use in the basin is dominated by woodland, grassland and paddy fields. Economic and social development has had a certain impact on the land use structure of the Erhai Basin (Li, 2011).

The total area of the Fuxian Lake Basin is 690.03 km^2. The north of the lake is a basin, with fault cliffs or fault block mountains on the east and west sides, and alluvial plains on the south (Kang, 2011). Since the 1980s, unreasonable development of human activities have caused some damage to the land use structure of the lake basin. However, in recent years, with the emphasis on the ecological environment of the lake basin, the land use structure has gradually been optimized and the lake has always been Class I water quality (Wu, 2002).

Data sources

Part of the research data is from Landsat OLI remote sensing image data from the three major lake basins. The shooting time was March 2015, the line number of Dianchi Basin, Fuxian Lake Basin and Erhai Basin are 43, 43 and 42, respectively, and the band number is 129, 129 and 131, respectively. According to the classification standard of land use status (GB/T 21010-2007), combined with land use status, land use types are

divided into the dry land, paddy fields, garden lands, forest land, grass land, construction land, water area and unused lands eight types. Used spatial information technology (GIS/RS) and ERDAS software, based on the correction and enhancement processing of remote sensing images in the three lake basins, training samples were selected, supervised classification was conducted, and data such as land use type and area were further extracted. The other part comes from environmental protection agencies and their websites in Yunnan Province, Kunming City, and Dali Prefecture, as well as relevant data released in the "Yunnan Province Environmental Status Bulletin", "Kunming City Environmental Status Bulletin" and "Dali Prefecture Environmental Status Bulletin".
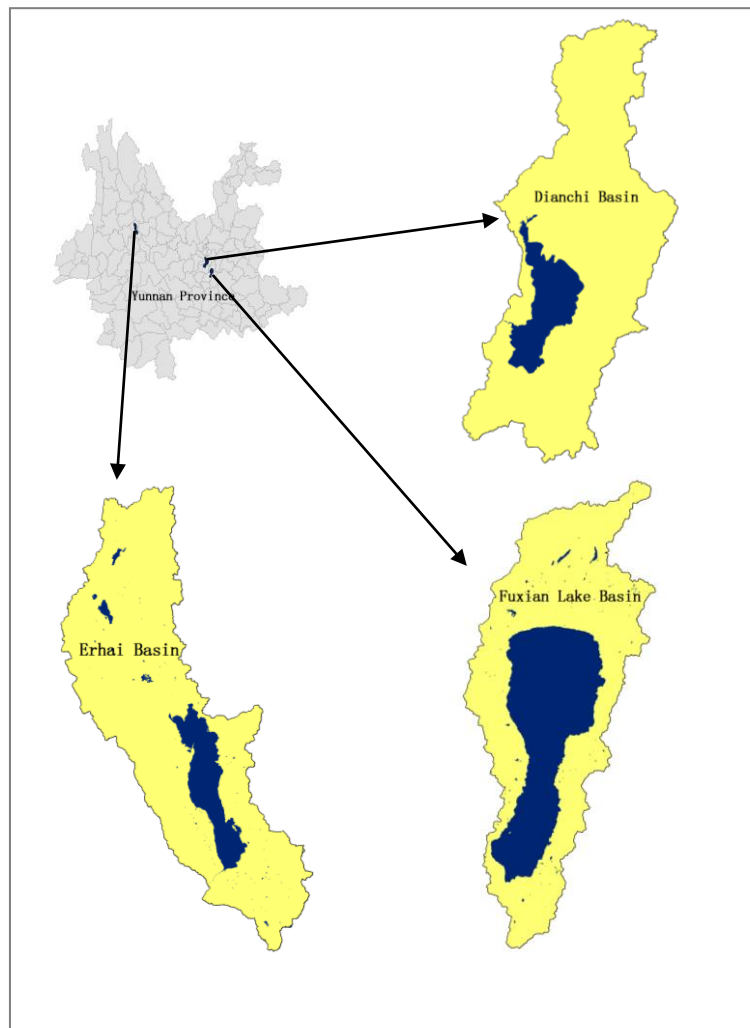

Figure 1. Study areas

Research methods

Analysis method of characteristics of land use landscape pattern

Based on the analysis methods of landscape ecology on quantitative structure, the land use diversity, evenness, dominance and fragmentation index of the three lake

basins were obtained, and the characteristics of land use landscape patterns were analyzed (Liu et al., 2008). The formula is as follows:

- Diversity index (*Eq. 1*)

$$SHDI = -\sum_{i=1}^{m} \left(p_i \ln p_i \right) \tag{Eq.1}$$

In the formula,, "*SHDI*" is the diversity index, "P_i" is the ratio of landscape plaque type "*i*", and "*m*" is the landscape type.

- Evenness index (*Eq. 2*)

$$SHEI = \frac{H}{H_{max}} = \frac{-\sum_{k=1}^{n} P_k \ln(P_k)}{\ln(m)} \tag{Eq.2}$$

In the formula,, "*SHEI*" is the evenness index, "*H*" is the measured diversity index, "H_{max}" is the maximum diversity index, and "*m*" is the landscape type.

- Dominance index (*Eq. 3*)

$$LDI = H_{max} + \sum_{i=1}^{m} P_i \ln(P_i) \tag{Eq.3}$$

In the formula,, "*LDI*" is the dominance index, "H_{max}" is the maximum diversity index, "P_i" is the ratio of landscape plaque type "*i*", and "*m*" is the landscape type.

- Fragmentation index (*Eq. 4*)

$$LFI = \sum N_i / \sum A_i \tag{Eq.4}$$

In the formula,, "*LEI*" is the fragmentation index, "N_i" is the number of plaques in class "*i*", and "A_i" is the total area of class "*i*".

The method of ecological environment evaluation

- Build an evaluation system

Referring to the "Technical Specifications for Eco-environmental Status Assessment" (HJ 192-2015) (Ministry of Ecological and Environment of the People's Republic of China, 2016), published in 2015 by the Ministry of environmental protection, and combined the geographical features of the three lake basins, the evaluation indexes were selected according to the principles of objectivity, comprehensiveness, evaluability, independence and hierarchy. Then the Analytic Hierarchy Process (AHP) was used to determine the degree of association between the adjacent level evaluation indexes in the structural model. For indexes that belong to the same level, the above-mentioned index elements are the criteria. We constructed the pairwise judgment matrix by "1-9 scale method", compared the importance of the evaluation indicators, and calculated the relative weight values until it passed the

consistency check (CR < 0.1000). Because the selection of each index is extensive and the directions of the indicators are inconsistent, in order to eliminate the influence of the unit of measure, dimension and magnitude differences on the evaluation results, and make the indexes comparable and in the same direction, the linear data is used for non-dimensional treatment of the initial data (*Eqs. 5* and *6*). The evaluation indicator system for the ecological environment of the three lake basins is shown in *Table 1,* and the classification criteria for the evaluation results are shown in *Table 2*.

Index dimensionless processing formula:

$$Y = \frac{X}{X_{max}} \text{ (Positive indicators)} \tag{Eq.5}$$

$$Y = \frac{X_{min}}{X} \text{ (Negative indicators)} \tag{Eq.6}$$

In the formula, "X" is the original value of a certain evaluation factor, "X_{max}" is the maximum value of a parameter, and "X_{min}" is the minimum value of a parameter.

Table 1. Evaluation index system of ecological environment in three lake basins

Target layer	Rule layer	Direction	Weight	Index layer	Weight
Ecological environment quality index (EI)	Biological abundance index (A1)	Positive	0.1589	Arable land ratio (A11)	0.1799
				Forestland area ratio (A12)	0.2965
				Grassland area ratio (A13)	0.2965
				Construction land area ratio (A14)	0.0700
				Wetland area ratio (A15)	0.1112
				Unused area ratio (A16)	0.0460
	Vegetation coverage index (A2)	Positive	0.1589	Forestland area ratio (A21)	0.5695
				Grassland area ratio (A22)	0.3331
				Arable land ratio (A23)	0.0974
	Water network density index (A3)	Positive	0.0967	Water resources/Total area (A31)	0.4934
				Wetland area/ Total area (A32)	0.3108
				The length of the river/Total area (A33)	0.1958
	Soil erosion index (A4)	Negative	0.2409	Severe erosion area ratio (A41)	0.6370
				Moderate erosion area ratio (A42)	0.2583
				Slight erosion area ratio (A43)	0.1047
	Pollution load index (A5)	Negative	0.3447	COD/Total annual precipitation in the region (A51)	0.3000
				NH3—N/Total annual precipitation in the region (A52)	0.3000
				SO2/Total area (A53)	0.3000
				Solid waste emissions/Total area (A54)	0.1000

Table 2. *Classification criteria for evaluation results of ecological environment*

Level	Index	Status
Excellent	EI ≥ 0.75	Vegetation coverage, biodiversity, and ecological conditions are the best
Good	$0.55 \leq EI < 0.75$	Vegetation coverage, biodiversity, and ecological environment are better
General	$0.35 \leq EI < 0.55$	Vegetation coverage, biodiversity, and ecological conditions are normal
Poor	$0.20 \leq EI < 0.35$	The vegetation coverage is poor, with severe drought and less rain, fewer species, and poor ecological environment
Worst	EI < 0.20	Ecological environment and its bad conditions

- Establish a comprehensive evaluation model

Individual indicators include biological abundance index, vegetation coverage index, water network density index, soil erosion index, and pollution load index, which are the composite of different basic indicators of each criterion level. Every single index reflects ecological environmental quality from different aspects, and the calculation of the single index adopted the method of the multi-factor linear weighting function, the calculation formula is as follows (*Eq. 7*):

$$B_i = \sum_{j=1}^{n} Gj * Wj \qquad (Eq.7)$$

In the formula, "B_i" is every single index,, "G_j" is the index score corresponding to each specific evaluation index, and "W_j" is the weight of corresponding evaluation index.

The single-item index evaluated the priority of ecological environment quality in a certain aspect, and a comprehensive evaluation must be conducted to fully reveal. The formula is as follows (*Eq. 8*):

$$B = \sum_{i=1}^{n} Bi * Wi \qquad (Eq.8)$$

In the formula, "*B*" is the total evaluation score, "B_i" *(i = 1, 2, 3)* is the individual index, "W_i" is the weight corresponding to the basic indicators of each criterion level, the standard value of each indicator is weighted and averaged on a layer-by-layer basis to obtain a composite index.

Results

Through remote sensing image interpretation, land use remote sensing classification maps of three lake basins were obtained (*Fig. 2*), and landscape pattern index is shown in *Table 3*.

Table 3. *Land use landscape pattern index of three lake basins*

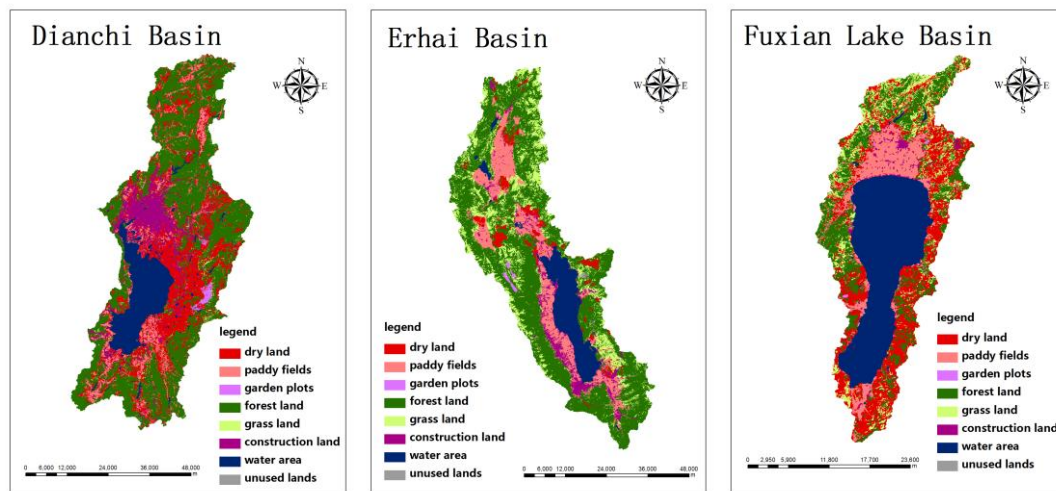| Basins	Diversity index	Evenness index	Dominance index	Fragmentation index
Dianchi Basin	1.2966	0.6663	0.6493	0.1780
Erhai Basin	1.3569	0.6973	0.5890	0.0616
Fuxian Lake Basin	1.3852	0.7119	0.5607	0.1167

Figure 2. *Classification map of land use in the three major lake basins*

Analysis of landscape pattern characteristics of land use

According to *Table 3,* the landscape pattern of the three lake basins was analyzed horizontally horizontally, that is, the different indexes of the same basin were analyzed, and the results were as follows:

(1) In Dianchi Basin, the diversity index and evenness index were the smallest, while the dominant index and fragmentation index were the largest, indicating that the diversity of landscape structure of land use in Dianchi Basin was the worst, the landscape types were unevenly distributed, and the degree of landscape fragmentation was the most serious;

(2) In addition to the lowest fragmentation index in the Erhai Basin, the diversity, evenness, and fragmentation index are all in the middle level and are closer to the Fuxian Lake Basin. Therefore, overall, the diversity of land use landscape structure in the basin is relatively good. The type distribution is more uniform, and the landscape type is divided into smaller segments with the best connectivity.

(3) The diversity index and evenness index of the Fuxian Lake Basin are the largest, the dominance index is the lowest, and the fragmentation index is at the intermediate level. Based on the comprehensive analysis, the land use landscape structure of the basin is the simplest, and the level of human disturbance is the lowest.

The landscape pattern of the three major lake basins was analyzed longitudinally, that is, the same index of different watersheds is analyzed. The results are as follows:

(1) The order of diversity index which is Fuxian Lake Basin > Erhai Basin > Dianchi Basin, 1.3852, 1.3569, and 1.2966, respectively. The diversity of landscape structure of land use in Dianchi Basin was the lowest, the landscape diversity was poor, and the coordination of various landscape types was low. The diversity of landscape structure of land use in Fuxian Lake Basin was the highest, and the diversity of landscape was well maintained. The degree of coordination is high; the diversity of the Erhai Basin is between the two.

(2) The ranking of evenness index which is Fuxian Lake Basin > Erhai Basin > Dianchi Basin, which is 0.7119, 0.6973, and 0.6663, respectively. The dominance index ranking is Dianchi Basin > Erhai Basin > Fuxian Lake Basin, which are 0.6493, 0.5890,

and 0.5607, respectively. It showed that the balance of land use landscape structure in Dianchi Basin is poor, and the distribution of land use types is uneven. This is mainly due to the fact that the proportion of forest land and cultivated land in the basin is large, which greatly improves the dominance of the overall landscape. The balance of land use structure in the Fuxian Lake Basin is relatively good, with a balanced distribution across the regions; the landscape evenness in the Erhai Basin is located between the two.

(3) Fragmentation index ranking which is Dianchi Lake Basin > Fuxian Lake Basin > Erhai Lake Basin, which is 0.1780, 0.1167, and 0.0616, respectively. The result showed that the landscape pattern of land use in Dianchi Basin has the highest degree of fragmentation, and the landscape is the most severely fragmented. This is mainly because the Dianchi Basin is located in a karst landscape area and the degree of rocky desertification is relatively deep, resulting in serious landscape fragmentation; The higher degree of fragmentation of land-use landscape structures in the Fuxian Lake Basin is because the basin is located in the central part of the central basin of the central Yunnan basin and the watershed of the Zhujiang River system. The surrounding area is mostly eroded by fault blocks, and the terrain is undulating, scattered and distributed on both sides of the lake. There are 61 sub-watersheds, and special geological conditions have caused great fragmentation of the terrain of the Fuxian Lake Basin. The fragmentation of land use landscape structures in the Erhai Basin is the lowest.

The evaluation results of the ecological environment of the three lake basins

According to *Table 4,* the "*EI*" indexes of the Dianchi Basin, the Erhai Basin, and the Fuxian Lake Basin are 0.5628, 0.7274, and 0.7413, respectively. They are all between 0.55 and 0.75. It showed that the three lake basins have good vegetation coverage, good biodiversity, and good ecological environment.

Table 4. Evaluation results of ecological environment in the three lake basins

Evaluation index	Dianchi Basin	Erhai Basin	Fuxian Lake Basin
Biological abundance index (A1)	0.7431	1.0000	0.9624
Vegetation coverage index (A2)	0.6811	1.0000	0.6010
Water network density index (A3)	0.1608	0.1519	1.0000
Soil erosion index (A4)	1.0000	0.9345	0.2135
Pollution load index (A5)	0.2322	0.4926	1.0000
Ecological environment quality index (EI)	0.5628	0.7274	0.7413

Comparative analysis showed that the "*EI*" index is the lowest in the Dianchi Basin, and the ecological environment is the worst in the three lake basins. The "*EI*" index of Erhai Basin is slightly lower than that of Fuxian Lake Basin, which is larger than the Dianchi Basin, and its ecological environment is better than that of the Dianchi Basin, which is slightly inferior to Fuxian Lake Basin. The "*EI*" index is the highest in Fuxian Lake Basin, and the ecological environment is better than the other two lake basins.

Comprehensive analysis of the landscape pattern of land use and eco-environment characteristics

The comprehensive analysis was made on the landscape pattern index of land use and ecological environment index in the three lake basins. The Dianchi Basin landscape

diversity index and evenness index were the smallest, while the dominance index and fragmentation index were the largest, the ecological environment index was the smallest, and the fragmentation degree of the Erhai Basin was the smallest. In addition to the lowest fragmentation index in the Erhai Basin, the other indices are all in the middle level. The landscape diversity index and evenness index of the Fuxian Lake Basin are the largest, the dominance index is the smallest, the fragmentation index is small, and the ecological environment index is the largest (*Fig. 3*).
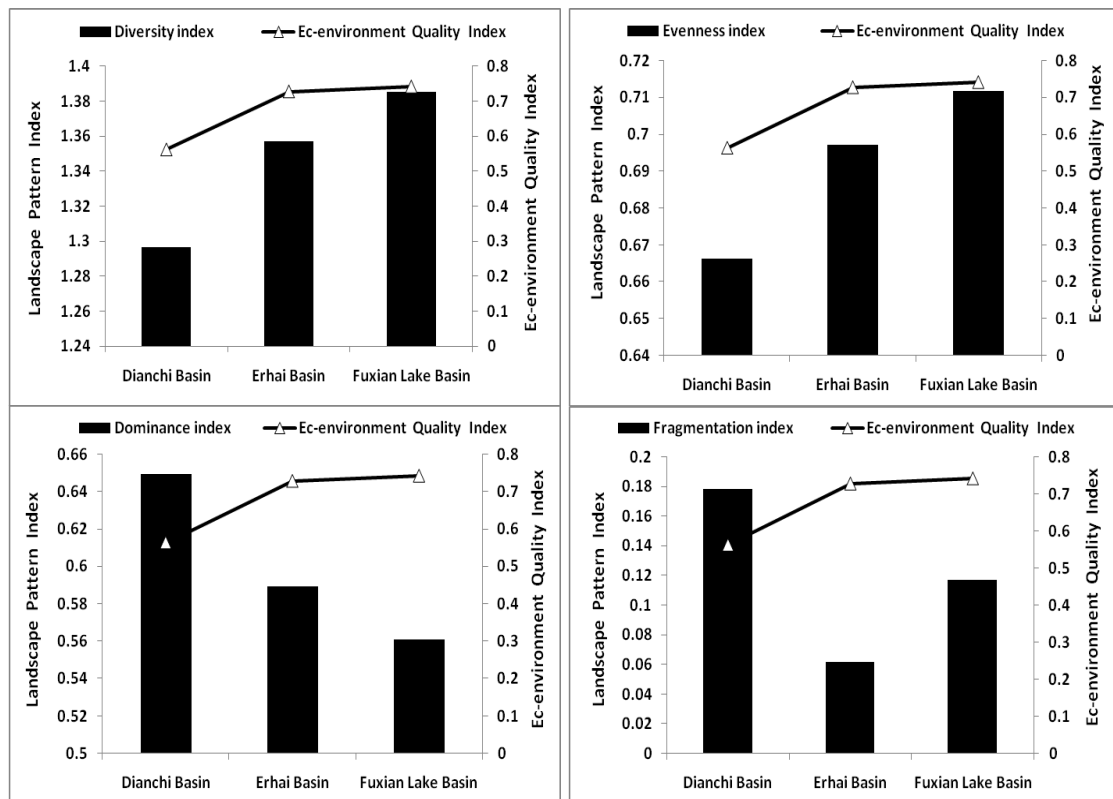

Figure 3. *Landscape pattern index and eco-environment quality index of land use in the three major lake basins*

Through comparison, it is found that the landscape patterns of land use in the three lake basins are closely related to the status of the ecological environment, and the landscape diversity and evenness of the basins with good ecological environment quality are relatively high, and the degree of landscape fragmentation is relatively low. On the contrary, in the basin with poor ecological environment, the degree of diversity and evenness of landscape is relatively low, and the degree of landscape fragmentation is relatively high.

Based on the analysis of the socio-economic development level of the three lake basins, the landscape pattern of land use and eco-environment characteristics of the three lake basins are related to the socio-economic development level of the lake basins. The Dianchi Basin with the highest level of economic development has the lowest landscape diversity. The distribution of landscape types is the lowest, the degree of landscape segmentation is the highest, and the quality of ecological environment is the lowest. The degree of landscape diversity and landscape types in the Erhai Basin and

Fuxian Lake Basin with a lower level of economic development are relatively evenly distributed. The degree of landscape fragmentation is relatively low, and the quality of ecological environment is the best.

Discussion

At present, there are many researches on the landscape pattern of land use, and the results are relatively fruitful, but mainly based on the study of landscape patterns in different phases of the same study area, and the lateral contrast analysis between different regions of the same time phase is less, most of them take city, county and other areas as the research scale, and few studies take plateau lake basin as the object. This study conducted a comparative analysis on the landscape pattern of land use and eco-environment characteristics among different plateau lake basins in Yunnan Province of China, which can provide scientific basis for optimizing the landscape pattern of land use and protecting the ecological environment. Because the factors affecting regional landscape pattern of land use and ecological environment quality are complex, involving natural conditions such as climate, topography, vegetation, hydrology, and socio-economic factors such as population and economic level, this study is only a brief description from the macro aspect, the next step will focus on the driving factors that affect the landscape pattern and the ecological environment of different basins, so as to make the research more perfect and scientific.

Conclusion

(1) From the analysis of the land use landscape pattern of the lake basins, the degree of landscape diversity and the degree of evenness are the highest in the Fuxian Lake Basin, followed by the Erhai Basin, and the lowest is the Dianchi Basin; the fragmentation of the landscape is highest in the Dianchi Basin and followed by the Fuxian Lake Basin. The lowest is the Erhai Basin.

(2) According to the results of the ecological environmental quality assessment, Dianchi Basin is the worst, while the Erhai Basin and Fuxian Lake Basin are better, and the Fuxian Lake Basin is the best.

(3) The landscape pattern of land use in the basin is closely related to the quality of the ecological environment. Basins with good ecological environment quality have a relatively high degree of diversity and evenness, and relatively low fragmentation; in the basins with poor ecological environment, the degree of landscape evenness and diversity are relatively low, and the degree of landscape fragmentation is relatively high.

The landscape pattern of land use is closely related to the ecological environment, unreasonable land use is one of the important factors of lake pollution, therefore, the relationship between land use and lake water quality should be further explored on the basis of this study, so as to better alleviate the pollution and improve the ecological environment of the lake basins from the perspective of land use.

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