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# Research on Landscape Pattern Revolution of Land Use in Fuxian Lake Basin Based on RS and GIS

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***Abstract*****—**Based on the remote image data of land use in the four periods of 1980, 1995, 2005 and 2015, this study quantitatively analyzed the dynamic variation of landscape transfer and landscape pattern in the Fuxian Lake basin by constructing a land use dynamic variation model and using ArcGIS 10.5 and Fragstats 4.2. The results indicate that: (1) From the perspective of land use landscape transfer, the intensity of land use is slowly rising from 1980 to 2015, and the main reduction landscape type is farmland and its net amount of transfer-out is the most among all transfer-outs, which is to 788.85 $hm^2$, the main added landscape type is construction land and its net amount of transfer-in is the most, which is to 475.23 $hm^2$. Meanwhile, the land use landscape variation in the stage of 2005-2015 showed the most severe among three periods when compared with other two stages. (2) From the perspective of land use landscape variation, significant spatial differences are shown, the changes in the north of the basin are significantly higher than that in the south, the west coast are apparently higher than the east. (3) From the perspective of landscape pattern index, the number of plaques is on the increase in the periods of 35 years in the basin, and there is little mutual interference between landscape patterns because the plaques are relatively discrete. Cultivated land showed a trend of fragmentation but constructive land showed trend of relative concentration. The sustainable development and biodiversity in this basin are under threat for the fragmented landscape pattern and the poorer connectivity.

***Keywords*****—**Land use, landscape pattern evolution, landscape pattern index, Fuxian Lake basin.

## I. Introduction

CHINA has entered the period of rapid urbanization and is in the transition stage of post-industrialization. A series of problems such as farmland occupied by urban expansion, unreasonable land use structure, serious land environmental pollution, and biodiversity reduction occur frequently, which cause the complexity of the evolution of land use landscape pattern and the fragility of ecosystem [1]. At present, land use/ land cover change and landscape pattern change have become a long-term focus in the field of geography and landscape ecology [2], [3], and are of great significance to the sustainable development of human society/nature [4]. Landscape pattern refers to the spatial distribution and combination of landscape elements with different sizes and shapes, which has important ecological significance to reflect the spatial information of a region [5], [6]. The vulnerability of landscape pattern mainly reflects the disturbance and vulnerability of landscape ecosystem under the influence of external factors [7]. As a very important geographical unit that bears the relationship between people and the environment, the study of landscape pattern and vulnerability is of great significance for the rational development and social development of the basin [8]. Therefore, through the evolution of landscape pattern, we can understand the evolution characteristics of various landscape elements, reveal the mechanism and law of landscape evolution, and provide reference for the sustainable use of land resources [9].

Scholars at home and abroad have done a lot of research on the evolution of landscape pattern of land use. From abroad, Turner [10], Skole [11], Ojima [12] used the comparative case study method to conduct qualitative research on the impact of environmental change and human activities on global land use change. Fischer [13] took welfare analysis as the starting point, simulated land use changes in different time and space, and studied socio- economic drivers. Otsubo [14], a Japanese scholar, adopted correlation analysis method, combined economic model and quantitative model, simulated land use change and policy environment with Kane Simulation Model (KSIM) and other simulation methods, and quantitatively studied the process of regional land use change. From a domestic perspective, Zhao et al. used the change trajectory analysis method and landscape index to characterize the evolution process of cultivated land landscape in the middle Heihe River, and adopted partial least squares regression model to analyze the driving force of cultivated land landscape evolution [16]. Tong et al. analyzed the temporal and spatial changes and driving factors of land use/landcover and landscape pattern in Nanjing in recent 30 years from the aspects of land use type structure, change rate, transformation relationship and landscape pattern [17]. Chen et al. interpreted remote sensing images with the help of RS and GIS technology, and analyzed the changes of landscape pattern structure of land use in Putian City [18]. Based on the information of landscape types, InVEST model, CA-Markov model and Logistic regression model were used to analyze the evolution of landscape pattern and habitat quality in Wuhan City and make predictions [19]. Supported by GIS and landscape pattern analysis software, Chu [19] analyzed the change of landscape pattern of land use and its ecological risks in Dexing City, Jiangxi Province. Given the above, scholars at home and abroad are mostly based on RS, GIS and landscape pattern analysis technology, in big cities such as typical area as the

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study area [20]-[22], driving through the change of land use, land use, structure prediction, landscape index and landscape ecological risk analysis of landscape pattern of land use evolution, but based on the perspective of land use change and landscape vulnerability research in the evolution of the landscape pattern of land use is relatively rare.

As an important ecological environment zone in Yunnan Province, Fuxian Lake basin has special geographical location and ecological environment system. In recent years, however, with the development of social economy, the rapid increase of population, reclaiming land from lakes is frequent, the growing industrial and agricultural pollution, land degradation, the lake problem such as plankton increase gradually, the different degrees of damage to the natural environment [23], which brought variations of the land use landscape pattern. At present, domestic scholars' research on Fuxian Lake basin is mostly based on the analysis of land use change and driving force [10], land use change and scenario simulation geological and geomorphic characteristics, environmental change and ecological environment monitoring, etc., and there is little research on the evolution characteristics of land use landscape pattern [24]. This paper analyzed the dynamic change of land use and characteristics of landscape pattern revolution during the past 35 years, basing on the remote sensing images from 1980 to 2015, with a combined analysis of ArcGIS10.5 and Fragstats 4.2 software. This research is to contextualize the ideology of environment being invaluable assets of human, and mountains, water, forests, farmland, lake and grass being a community, and it provides academic support for administrators to make decisions. It also lays a foundation for the ecological environment monitoring of nine plateau lakes in Yunnan province, and provides reference for the rational use of land resources and the coordinated development of social economy and ecology in Fuxian Lake basin.

## II. Materials and Methods

### A. Regional Overview

Fuxian Lake, the largest deep freshwater lake in China, located between 24°29′N-24°48′N, 102°53′E-102°88′E, is in a central city of Yunnan province, Yuxi city, stretching Chengjiang, Jiangchuan and Huaning counties. It is also seated in the center of Dianzhong Basin. Fuxian Lake basin is surrounded by mountains, two Lacustrine - alluvial plains are formed at the north and south of it. Higher in the north, west and south and lower in the east, Fuxian Lake belongs to fault and subsidence lake, with an altitude of 1721 meters. The lake has a climate of subtropical plateau sub-humid monsoon, with annual average temperature of 15.5 ℃, annual rainfall of 800-1100 mm, annual evaporation of 1300-1800 mm, and sunshine hours of 2000-2400 h [24]. As one of the nine plateau lakes in Yunnan province, with the basin area of 1084 square meters, it is China's largest deep-water freshwater lake and the first lake of the source of Pearl River [23], belonging to Nanpan river water system, and is proven the second deep-water lakes in our country, with a reservoir capacity only inferior to China's largest freshwater lake, and mufti-functions on fishery, watering, flood control, water supply for industry, agriculture, household and tourism, which help earn its own a name of "plateau pearl of central Yunnan". It is not only an important resource guarantee for the sustainable social and economic development of central Yunnan, but also a strategic water resource for the development of extensive pearl river delta region, and a source of drinking water of great strategic significance for the basin of Pearl River and the southwest region of China.

Well-known as the barn of central Yunnan, hometown of Yunnan Cigarette and bread-basket, Fuxian Lake basin is fertile and productive. Water quality is one of the best of natural lakes in China, with a rank of I (water quality ranking) [26]. The population is about 0.1603 million. The land is mainly covered by grass, shrub and coniferous forests, and its mainstream rural economy is planting rice, corn and wheat etc. Tobacco and rape are the economic corps. Phosphorus chemical industry is mainly used in building materials food processing and aquatic products, among which phosphorus chemical industry is the pillar industry in this region.

The land use is dominated by forests and water, but in recent years, as the rapid development of industry, agriculture and tourism, the demands of land use for buildings of multi-purpose and holding international races have been in the rise, which to some extent transforms the type of land use/landcover and landscape pattern in Fuxian Lake basin.

### B. Data Source and Processing

In order to make a long-time sequence variation analysis on the study area, four phases of remote sensing images were acquired from a geographic data cloud (http://www.gscloud.cn), including 1980, 1995, 2005 and 2015. The data of land of 1980 were obtained from Landsat- MSS remote sensing images, data of 1995 and 2005 came from Landsat-TM/ETM images, and data of 2015 were updated by using Landsat 8 remote sensing images, adding vector administrative boundaries and creating four phases of images of study areas, during which the four phases are unified to ensure that the results achieved from the remote sensing interpretation are comparable. The interpretation system is categorized into three levels, which is mainly based on land resources and their utilization attributes. Since the study area does not involve unused land, the land use data in this study are mainly divided into 5 categories: farmland, woodland, grassland, water area, and construction land. With the help of remote sensing data processing software ENVI5.3, the images were corrected geometrically and enhanced. Besides, the interpretation through man-machine interaction on the platform of ArcGIS10.5 was adopted and data were classified by the maximum likelihood method under supervised classification, and furthered corrected by referring to the high-definition image of Google Earth. The current figures of 1980, 1995, 2005 and 2015 land use of Fuxian Lake basin were received.

### C. Methodology

1. Land Use Dynamic Change Model

*a. Land Use Type Transfer Matrix*

Transfer matrix is composed of inter-transferred probabilities of area among different types of lands, which can reflect the number of land transformation during a certain phase. Not only does it help the researchers to learn the changing tendency of various types of land at the outset of a research, but also facilitates the studies on resources and composition at the final stage of a research; namely, the changing direction and number of area change of land use type in different phases will be accessible. Consequently, a transfer matrix representing the numerical relationship of inter-change amid different types of land use is calculated [25], [26] to reveal the revolution process of land use pattern from time and space. The mathematical model is:

$$S_{ij} = \begin{vmatrix} S_{11} & S_{12} & \dots & S_{1n} \\ S_{21} & S_{22} & \dots & S_{2n} \\ \dots & \dots & \dots & \dots \\ S_{n1} & S_{n1} & \dots & S_{nn} \end{vmatrix} \quad (1)$$

2. Comprehensive Index of Land Use Degree

Comprehensive index of land use degree can reflect the width and depth of land use of a region at a certain period, because it not only reflects the natural attribute of land use, but mirrors an intertwined effect between human elements and natural factors [27]. Basing on the conclusions of past researches [28], and combining the reality of regional researches, land use degree of different land use types which has been categorized into farmland, forest, grass, water and construction land under the influence of social activities was leveled as five degrees, shown in Table I. Then, a quantitative formula of comprehensive index of land use degree can be obtained as [28]:

$$I = 100 \times \sum_{i=1}^{n} A_i \times C_i \qquad I \in [100, 400] \quad (2)$$

where $I$ is the comprehensive index of land use degree in the study region; $A_i$ is the leveled index of land use degree at $i$ level; $C_i$ is the percentage of land use degree at $i$ level; and $n$ is the number of leveled land use.

3. Index of Landscape Pattern

By referring to the previous studies on landscape condition, most of which were quantitative analysis from the level of type and landscape, this paper chooses 7 indicators of type level and 13 indicators of landscape level. At the level of type, PLAND, NP, PD, LPI, ED, MPS and AWMSI, were picked after considering area, number and length of plaques. At the level of landscape, the point view of heterogeneity of landscape, NP, PD, MPS, AWMSI, AWMPFE, MPI, MNN, CONTAG, IJI, COHESION, SHDI, SHEI and AI will be used.

The calculated formula and ecological significance of the above indexes can be found in literature review [29], [30].

TABLE I
LAND USE DEGREE GRADING INDEX

| Level of Land Use type | Sub-type | Grading index |
|---|---|---|
| Unused land | Unused or not accessible land | 1 |
| Forest, grass and water | Forest, grass and water | 2 |
| Agricultural land | Farmland, garden, man-made forests and grassland | 3 |
| Construction land | Towns, residents, land of industry and mining, land of transportation | 4 |

## III. RESULTS AND ANALYSIS

### A. Analysis of Land Use Change

1. Dynamic Landscape Change Feature of Land Use

From 1980 to 2015, the main landscape type was predominated by water, taking up more than 30% of the total area of the basin and consisting of the advantageous landscape of the area, and these changes little during the study period. A second high-quality landscape type includes farmland and forest. Constricted by topographic, the farmland is mainly distributed in the relatively flat lacustrine- alluvial plain, mostly in the north of Fuxian Lake basin. During the study period, the proportion of farmland showed a continuing tendency of waning, with the most lessened area in the basin. Compared with 1980, the ratio of the farmland area in the basin was decreased by 1.18%, due to the growing use of construction land and grassland. Meanwhile, the proportion of forests showcased a tendency of rising and then falling. The grassland is a third well-protected landscape, with a coverage more than 13% of the area and generally showing a trend of adding up. The construction land takes up the least of the basin area, but it kept expanding during the study period, with a proportion rising from 2.06% to 2.77% and area growing to 475.23 $hm^2$. From 1980 to 2015, the indexes of comprehensive land use degree are 230.14, 229.72, 230.26 and 230.38 respectively, showing a slow increase, which indicates that the land use is in a developing time, and the intensity of land use is accentuating moderately.

2. Landscape Transfer Feature of Land Use

During the span from 1980 to 1995, the total area changed was 1064.90 $hm^2$, accounting for the percentage of 1.59 (Table III). The main landscape change types were cultivated land transforming into non-cultivated land, and non-forest converting into forest. The conversion from non-cultivated land to cultivated land area is 93.22 $hm^2$ (Table III), but the transferred area reached 483.46 $hm^2$, accounting for 2.78% of the total cultivated land area in 1980. The conversion from non-forestland to forestland area reached 482.11 $hm^2$, accounting for 2.78% of the total forestland area in 1995. Another type of landscape transformation was the roll-out and in of grassland, in which 357.05 hm$^2$ grassland shifted into forest and 318.93 hm$^2$ other landscape types were transformed into grassland, majorly from the conversion of farmland and forest. The change of construction land area pinpointed at the decrease and increase of farmland, and a certain amount of rising in water area, which was greatly attributed to the transition of farmland, forest and grassland.

TABLE II
LAND USE LANDSCAPE TYPE STRUCTURE FROM 1980 TO 2015 (HM$^2$, %)

| Land Use type | 1980 | | 1995 | | 2005 | | 2015 | |
|---|---|---|---|---|---|---|---|---|
| | Area | Proportion | Area | Proportion | Area | Proportion | Area | Proportion |
| Farmland | 17415.15 | 26.03 | 17024.91 | 25.44 | 16938.19 | 25.31 | 16626.30 | 24.85 |
| Forest | 17039.21 | 25.47 | 17354.11 | 25.94 | 17196.55 | 25.70 | 17030.64 | 25.45 |
| Grassland | 9287.99 | 13.88 | 9249.87 | 13.82 | 9268.42 | 13.85 | 9550.53 | 14.27 |
| Water | 21791.67 | 32.57 | 21851.70 | 32.66 | 21851.70 | 32.66 | 21851.34 | 32.66 |
| Construction land | 1376.21 | 2.06 | 1429.65 | 2.14 | 1655.39 | 2.47 | 1851.44 | 2.77 |
| Comprehensive index of Land Use degree | 230.14 | | 229.72 | | 230.26 | | 230.38 | |

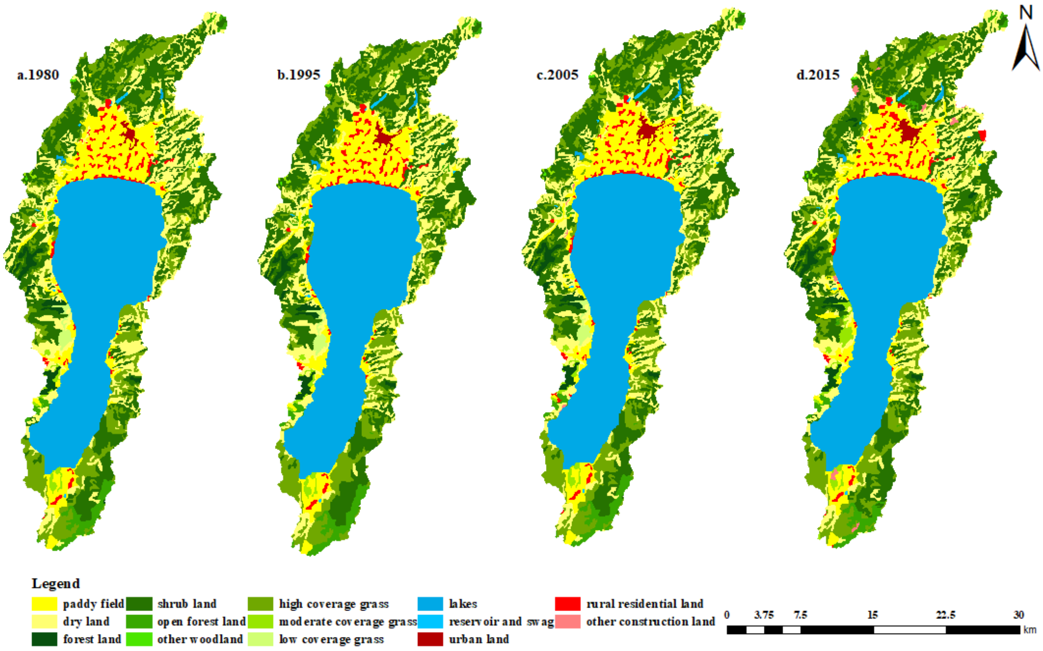


Fig. 1 Spatial distribution of land use landscape types in Fuxian Lake basin from 1980 to 2015

TABLE III
LAND USE LANDSCAPE TRANSFER MATRIX IN FUXIAN LAKE BASIN DURING 1980-1995 (HM$^2$)

| 1980 | 1995 | | | | | |
|---|---|---|---|---|---|---|
| | Farmland | Forest | Grassland | Water | Construction land | Total |
| Farmland | 0.00 | 1.95 | 41.85 | 0.00 | 49.42 | 93.22 |
| Forest | 171.40 | 0.00 | 306.66 | 0.00 | 4.05 | 482.11 |
| Grassland | 168.96 | 146.27 | 0.00 | 0.00 | 3.70 | 318.93 |
| Water | 32.49 | 18.99 | 8.55 | 0.00 | 0.00 | 60.03 |
| Construction land | 110.61 | 0.00 | 0.00 | 0.00 | 0.00 | 110.61 |
| Total | 483.46 | 167.22 | 357.05 | 0.00 | 57.17 | 1064.90 |

During the period from 1995 to 2005, the total area changed was 670.56 hm$^2$, accounting for the percentage of 1.00% (Table IV). The change in this time was relatively small, and the major transformation of landscape type is the conversion of farmland, forest and construction land. The rolled-in farmland was largely converted from forest and grassland, and the roll-out of farmland was the use of construction land, with a number of 210.07 hm$^2$, accounting for 1.23% of the total area of farmland in 1995. The main types of forest roll-out and in were farmland and grassland, and the water area was basically unchanged.

From 2005 to 2015, the total area changed was 1666.09 hm$^2$, accounting for the percentage of 2.49% (Table V), which showed the most dramatic change of land use. The main changes were the roll-out of farmland and forest which respectively reached up to an area of 569.89 $hm^2$ and 526.03 $hm^2$, taking up 3.36% and 3.06% of the total area, and roll-in of grassland, with an area of 667.03 $hm^2$, accounting for a percentage of 6.98 of 2015 total area. Other changes were the roll-out of grassland and roll-in of construction land, forest and farmland, with a respective area of 384.92 $hm^2$, 364.08 $hm^2$, 360.11 $hm^2$and 257.59 $hm^2$. The conversion of water was relatively stable.

TABLE IV
LAND USE LANDSCAPE TRANSFER MATRIX IN FUXIAN LAKE BASIN DURING 1995-2005 ($HM^2$)

| 1995 | 2005 | | | | | |
|---|---|---|---|---|---|---|
| | Farmland | Forest | Grassland | Water | Construction land | Total |
| Farmland | 0.00 | 122.50 | 85.94 | 0.00 | 0.27 | 208.72 |
| Forest | 45.78 | 0.00 | 40.93 | 0.00 | 0.00 | 86.71 |
| Grassland | 39.60 | 109.53 | 0.00 | 0.00 | 0.00 | 149.12 |
| Water | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Construction land | 210.07 | 12.24 | 3.70 | 0.00 | 0.00 | 226.01 |
| Total | 295.44 | 244.27 | 130.58 | 0.00 | 0.27 | 670.56 |

TABLE V
LAND USE LANDSCAPE TRANSFER MATRIX IN FUXIAN LAKE BASIN DURING 2005-2015 ($HM^2$)

| 2005 | 2015 | | | | | |
|---|---|---|---|---|---|---|
| | Farmland | Forest | Grassland | Water | Construction land | Total |
| Farmland | 0.00 | 64.29 | 16.19 | 17.28 | 159.84 | 257.59 |
| Forest | 69.57 | 0.00 | 287.39 | 0.09 | 3.06 | 360.11 |
| Grassland | 249.02 | 412.61 | 0.00 | 0.27 | 5.13 | 667.03 |
| Water | 0.00 | 17.28 | 0.00 | 0.00 | 0.00 | 17.28 |
| Construction land | 250.89 | 31.85 | 81.34 | 0.00 | 0.00 | 364.08 |
| Total | 569.48 | 526.03 | 384.92 | 17.64 | 168.03 | 1666.09 |

TABLE VI
LAND USE TRANSFER CHARACTERISTICS OF FUXIAN LAKE BASIN FROM 1980 TO 2015

| Time | Roll-out characteristics | Roll-in characteristics |
|---|---|---|
| 1980-1995 | In terms of quantity, farmland was mainly transferred out (483.46 $hm^2$), followed by grassland (357.05 $hm^2$). In terms of amplitude, the grass was mainly turned out, accounting for 3.84% of the total area before the turn- out. Next was the farmland roll-out, accounting for 2.78% of the total area before the transfer. | In terms of quantity, forest roll-in was the main one, which was 482.11 $hm^2$, followed by grassland roll-in, which was 318.93$hm^2$. In terms of amplitude, construction land transfer-in was the main part, accounting for 7.74% of the total area after the transfer, followed by grassland roll-in, accounting for 3.45% of the total area after the transfer. |
| 1995-2005 | In terms of quantity, farmland was mainly transferred out (295.44 $hm^2$), followed by forest land roll-out (244.27 $hm^2$). In terms of amplitude, the farmland was mainly transferred out, accounting for 1.74% of the total area before the transfer-out, followed by the grassland, accounting for 1.41% of the total area before the transfer-out. | In terms of quantity, the roll-in of construction land was the main one (226.01 $hm^2$), followed by the transfer-in of farmland (208.72 $hm^2$). In terms of amplitude, construction land roll-in was the main part, accounting for 13.65% of the total area after the transfer, followed by grassland roll-in, accounting for 1.61% of the total area. after the transfer |
| 2005-2015 | In terms of quantity, farmland was mainly transferred out (569.48 $hm^2$), followed by forest land (526.03 $hm^2$). In terms of amplitude, construction land was transferred out mainly, accounting for 10.15% of the total area before the transfer out, followed by grassland, accounting for 4.15% of the total area before the transfer-out. | In terms of quantity, the roll-in of grassland dominated, with a number of 667.03 $hm^2$, followed by the transfer of construction land, which was 364.08 $hm^2$. In terms of amplitude, the roll-in of the construction land was the main part, accounting for 19.66% of the total area after the transfer-in, followed by grassland roll-in, accounting for 6.98% of the total area after the transfer-in. |
| Similarities and differences of the change | In quantity, all changes were showing a dominance of farmland roll-out; and the conversion of grassland into forest followed. However, the amplitude of the change is more obvious, and the change is significantly increased in the third stage, displaying the most drastic change. | In terms of quantity, the main types changed greatly, from forest to construction land, then to grassland; followed by grassland to farmland, then to construction land. The amplitude of the major change types increased by a percentage of about 6, and the minor change types also showed an overall upward trend. |

Generally speaking, the totality of roll-in and roll-out of different landscape types showed a rising tendency (Fig. 2). Seen from the number, the roll-out of farmland was the largest, adding up to 1348.38 $hm^2$; meanwhile, the roll-in number was 559.53 $hm^2$, so that the net roll-out number was 788.85 $hm^2$. The second largest was the roll-in area of grassland, totally 1135.08 $hm^2$, and the roll-out number of it was 872.55 $hm^2$, with a net roll-in number of 262.53 $hm^2$. The third one was the roll-out area of forest, totaled 937.52 $hm^2$; because there was a near balance of roll-in and roll-out, the net roll-out number was only 8.59 $hm^2$. Finally, the roll-in amount of construction land was 700.70 $hm^2$, and the roll-out amount was 225.47 $hm^2$, thus the net roll-in amount was 475.23 $hm^2$.

Analyzed from different phases, the characteristics of roll-in and roll-out during three periods showed both similarities and differences (Table VI), among which the landscape change of Fuxian Lake basin land use from 2005 to 2015 was more obvious than the other two study periods, with the first phase of 1980 to 1995 following closely. In the third phase, except for water area and forest roll-in amount, the transfer amount of other major land use landscape types reached the maximum (Fig. 2). From 2005 to 2015, the entire roll-out amount of farmland accounted for 46.04% of the full roll-in amount of the three stages. The roll-out area of forest accounted for 56.11% of the total and roll-in amount did 38.77% of the whole. The amount of grassland roll-out accounted for 44.11% of the total, and the amount of roll-in accounted for 58.77%. The roll-out amount of construction land accounted for 74.52%, and the roll-in amount accounted for 51.96%. The results showed that the land use evolution was drastic from 2005 to 2015, and the construction land area increased obviously during the period when the social and economic development level was significantly improved. Meanwhile, the protection of Fuxian Lake as a type I water source was strengthened gradually, and the grassland area increased notably, from 9268.42 $hm^2$ in 2005 to 9550.53 $hm^2$ in 2015, with a net increase of 282.11 $hm^2$.

Analyzed from different landscape types of land use, the main sources of farmland intake were the development and reclamation of forest (188.75 $hm^2$), grassland (143.98 $hm^2$), and construction land (209.53 $hm^2$). The roll-in amount of forest mainly came from the conversion of farmland to forest (286.76 $hm^2$) and the conversion of grassland to forest (634.98 $hm^2$), accounting for 30.87% and 68.36% of the total conversion amount respectively. The amount of grassland transfer-in was mostly from returning farmland to grassland (457.58 $hm^2$) and returning forest to grassland (668.41 $hm^2$), respectively taking up a percentage of 40.31% and 58.89% of the total conversion. There was a certain amount of increase in water area, and farmland and forest conversion contributed to the most. The roll-in amount of construction land was predominantly from the farmland conversion, with a number of 571.56 $hm^2$, accounting for 81.57% of the total, indicating that the increase of construction land was obtained by sacrificing farmland (Fig. 3).

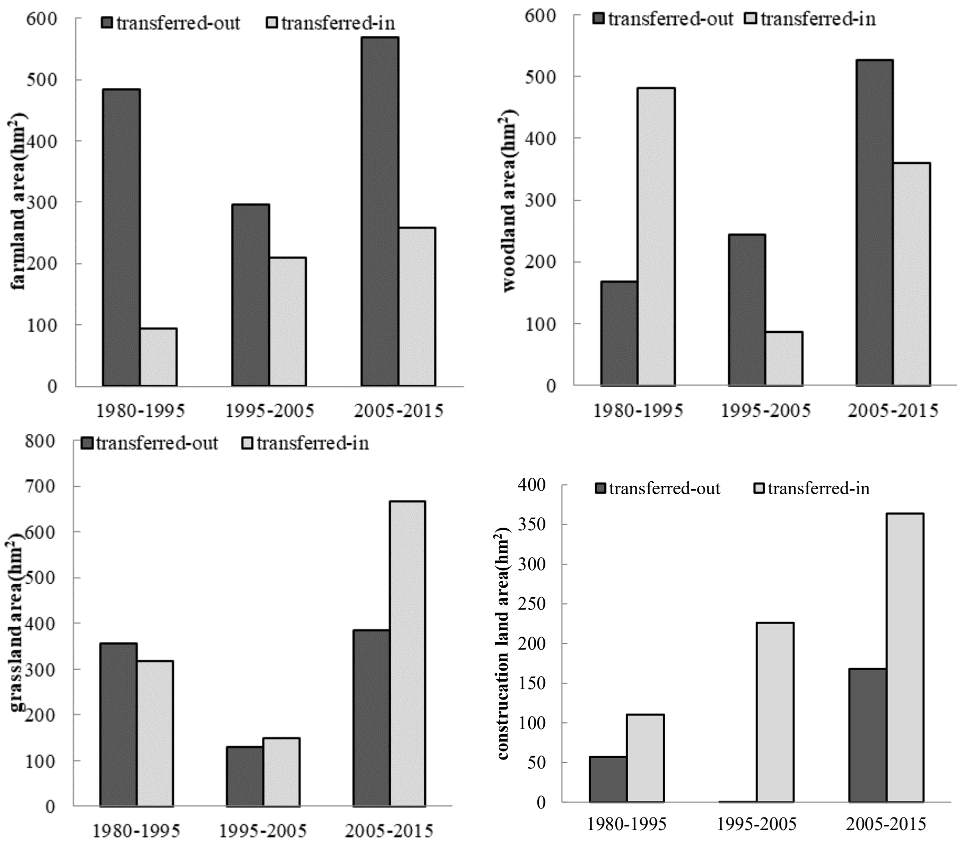


Fig. 2 Land use landscape type transfer in Fuxian Lake basin from 1980 to 2015

3. Spatial Landscape Change of Land Use

According to four phases of land use figures of Fuxian Lake basin in 1980, 1995, 2005 and 2015, the change of area and difference in spatial pattern of various land use landscape types in three phases were obtained through the analysis of the intersection superposition of two and two in Arcgis10.5 (Fig. 3). From the landscape-type change of land use, the water area was basically unchanged, the construction land showed a trend of expansion in all directions, and the density of construction land increased. The amounting of construction land mainly came from the absorption of farmland, followed by the obvious exchange of forest and grassland. Geographically analyzed, influenced by the topographic features, it was notable that the northern landscape types, being led by the conversion of construction land and farmland, presented a more remarkable change than the south, and the west than the east. Therefore, the changes of landscape type of land use in the western coastal areas were mainly manifested in the exchange of forest and grass land, the reclamation of construction land for farmland, the conversion of farmland to grassland and forest to improve the environment around the lake.

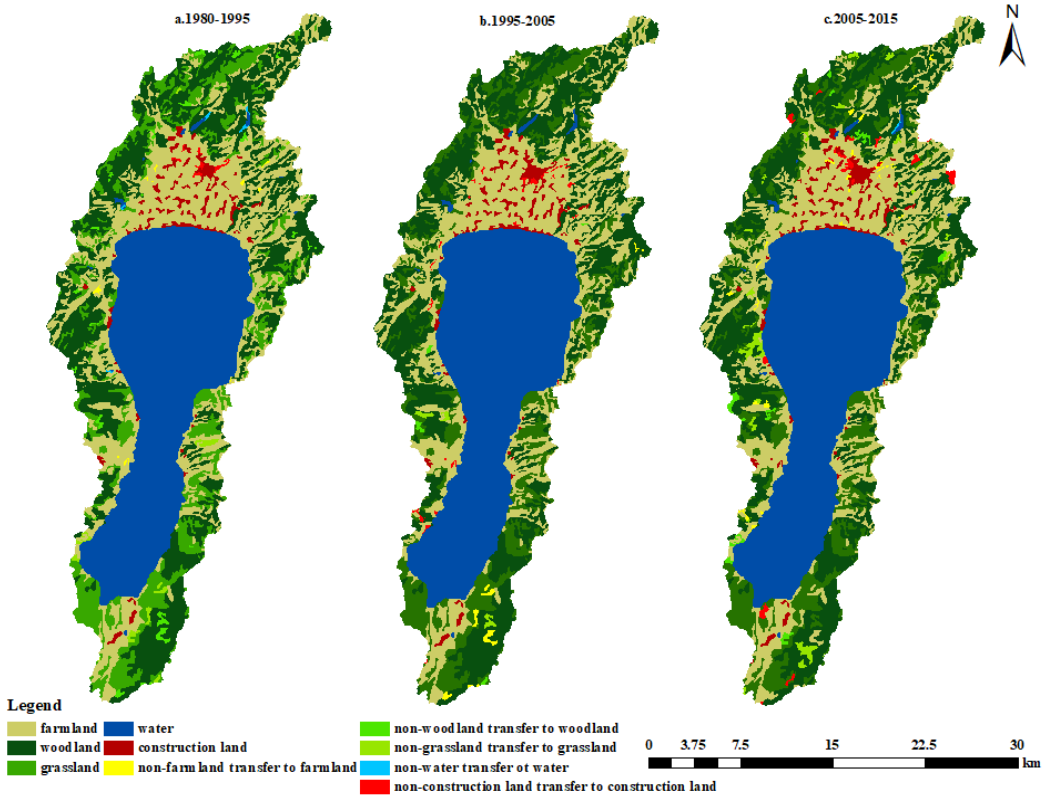


Fig. 3 Spatial changes of land use landscape pattern in Fuxian Lake basin from 1980 to 2015

### *B. Characteristics of Landscape Pattern Change*

With the support of Arcgis10.5, four Tiff grid maps were collected by rasterizing the land use vector maps of Fuxian Lake basin in the four phases of 1980, 1995, 2005 and 2015. Then, Fragstats4.2 was used to calculate to get the index of type of variant patch types (Table VII) and index of landscape level (Table VIII).

#### 1. Characteristics of Landscape Type Revolution

As shown in Table VII, the area of patch types of water, forest and farmland were relatively higher, constituting the main landscape elements and constructing the base types of this place. In the study period, both the ratio of patch type area and the index of the largest patch stood at a peak point, which indicated that water was the largest high-quality landscape. Having a low proportion at the patch type, grassland held the most number and highest intensity of patches, meanwhile a relatively small index of the biggest patch demonstrated that grassland distributed itself irregularly with high degree of fragmentation and low area. The indexes of patch characteristics of farmland and forest were very similar, there were not many disparities in the proportion of patch type area, average area of patch, patch intensity, number of patch and margin intensity. But as a result of increase in number and intensity of patches, both of them displayed a fragmentary inclination, and farmland manifested itself more obviously. In terms of average patch area, the distribution of grassland and construction land was more fragmented than that of other landscape types. In terms of the weighted average shape of the area, the landscape type of farmland has the highest complexity, followed by the forest, grassland construction land, and the lowest was the water landscape type. To some extent, the intensity of margin patch reflects the intensity of the edge effect of landscape. Notably, the margin intensity of forest and farmland was more intensified than any other landscape types; besides, they had a larger average patch area and index of the biggest patch, therefore indicating that these two types of landscape would have a more profound influence on the surrounding landscape types. The number and density of construction land patches increase, while the average patch area decreased, suggesting that the construction land showcased an inclination of spatial concentration.

#### 2. Characteristics of Landscape Pattern Revolution

Examined from the index of landscape pattern in Table VIII, in the scale of landscape, all the following indexes showed an uphill tendency, including the number of patches (fragmentation increasing), density of patches (fragmentation increasing), mean closest distance (distribution dispersion/

fewer interruptions between landscape patterns), weighted area fractal dimension (the increase of human repercussions on natural landscape), index of distribution and juxtaposition (dis-centralized), index of dispersion (fragmented and scattered), index of diversity (variety of land use and high degree of fragmentation), index of homogeneity (the main driving landscape type). This indicates that the number of patches in Fuxian Lake basin has been increasing over the past 35 years, the distribution among patches is relatively discrete, the mutual interference among landscape patterns is small, land use is rich, fragmentation is serious, and the dominant degree of the main landscape is decreasing. The main reason lies in the large-scale destruction of cultivated land, the reduction of the complexity of cultivated land landscape type, the increasing degree of fragmentation, and the increasing human disturbance to the landscape pattern. However, the average patch area (more fragmented) showed a downturn, along with index of expansion (more small patches, and more fragmented), weighted average shape (greater human intervention), index of average proximity (poorer connection between landscapes, higher degree of fragmentation among different patches or higher degree of landscape fragmentation) and the index of aggregation (dispersion). This indicates that over the past 35 years, the number of small patches in Fuxian Lake basin has gradually increased, the degree of dispersion among different patches is high or the degree of landscape fragmentation is high, the intensity of human activities tends to increase, the connectivity of landscape pattern tends to be poor, and the continuity between various landscape types is poor. Meanwhile, the slight change of index of patch connection designated that the change of land use type was moderate of Fuxian Lake basin amid the 35 years.

TABLE VII
PATCH CHARACTERISTIC INDEX OF LANDSCAPE ELEMENTS

| Landscape type | Year | PLAND/% | NP | PD/$10^{-2}$hm$^{-2}$ | PI/% | ED/m·hm$^{-2}$ | MPS/hm$^2$ | AWMSI |
|---|---|---|---|---|---|---|---|---|
| Farmland | 1980 | 26.02 | 104 | 0.1554 | 13.89 | 18.63 | 167.44 | 9.5563 |
| | 1995 | 25.44 | 97 | 0.1450 | 13.80 | 18.21 | 175.50 | 9.6909 |
| | 2005 | 25.33 | 106 | 0.1584 | 13.57 | 18.88 | 159.90 | 9.9731 |
| | 2015 | 24.88 | 109 | 0.1629 | 13.39 | 18.58 | 152.76 | 9.7757 |
| Forest | 1980 | 25.52 | 96 | 0.1435 | 6.60 | 16.67 | 177.85 | 6.5628 |
| | 1995 | 25.97 | 90 | 0.1345 | 6.77 | 15.93 | 193.07 | 6.3343 |
| | 2005 | 25.73 | 94 | 0.1405 | 6.77 | 16.39 | 183.19 | 6.3567 |
| | 2015 | 25.47 | 97 | 0.1450 | 6.66 | 16.86 | 175.70 | 6.675 |
| Grassland | 1980 | 13.84 | 157 | 0.2346 | 2.11 | 12.06 | 58.98 | 3.0128 |
| | 1995 | 13.81 | 150 | 0.2242 | 2.32 | 11.56 | 61.59 | 2.8897 |
| | 2005 | 13.82 | 152 | 0.2272 | 2.19 | 11.84 | 60.84 | 2.9821 |
| | 2015 | 14.23 | 165 | 0.2466 | 2.08 | 12.36 | 57.72 | 3.0105 |
| Water | 1980 | 32.56 | 11 | 0.0164 | 32.33 | 1.87 | 1980.88 | 1.7564 |
| | 1995 | 32.66 | 11 | 0.0164 | 32.33 | 1.96 | 1986.43 | 1.7582 |
| | 2005 | 32.66 | 11 | 0.0164 | 32.33 | 1.96 | 1986.43 | 1.7582 |
| | 2015 | 32.65 | 11 | 0.0164 | 32.33 | 1.93 | 1986.27 | 1.8869 |
| Construction land | 1980 | 2.06 | 66 | 0.0986 | 0.32 | 2.72 | 20.85 | 2.0052 |
| | 1995 | 2.13 | 56 | 0.0837 | 0.45 | 2.66 | 25.44 | 2.1715 |
| | 2005 | 2.46 | 83 | 0.1240 | 0.52 | 3.22 | 19.81 | 2.1306 |
| | 2015 | 2.76 | 80 | 0.1196 | 0.55 | 3.20 | 23.08 | 1.7564 |

TABLE VIII
CHANGES OF LANDSCAPE PATTERN INDEX AND ANNUAL MEAN VALUE

| Index of landscape | 1980 | 1995 | 2005 | 2015 |
|---|---|---|---|---|
| NP | 434 | 404 | 446 | 462 |
| PD (%) | 0.6486 | 0.6038 | 0.6665 | 0.6904 |
| MPS (hm$^2$) | 154.18 | 165.63 | 150.03 | 144.83 |
| AWMSI | 5.1917 | 5.1298 | 5.2009 | 5.1868 |
| AWMPFD | 1.1542 | 1.1525 | 1.1538 | 1.1538 |
| MPI | 124.13 | 125.24 | 125.95 | 123.29 |
| MNN | 398.43 | 400.91 | 378.91 | 419.04 |
| CONTAG (%) | 42.18 | 42.39 | 41.74 | 41.26 |
| IJI (%) | 67.86 | 68.46 | 69.43 | 70.17 |
| COHESION | 97.90 | 97.95 | 97.89 | 97.86 |
| SPLIT | 7.4676 | 7.4478 | 7.5176 | 7.5483 |
| SHDI | 1.4178 | 1.4192 | 1.4272 | 1.4365 |
| SHEI | 0.8809 | 0.8818 | 0.8868 | 0.8925 |
| AI | 87.86 | 88.24 | 87.78 | 87.64 |

Observed from the annual average of change, two conclusions could be made. On the one hand, in the 35 years from 1980 to 2015, the annual mean values of patch number, patch density, area-weighted average shape, area-weighted fractal dimension, scatter and parallel index, average patch area, average adjacency index, spread index and patch binding index in Fuxian Lake Basin generally showed a downward trend. This indicates that the number of patches in Fuxian Lake basin is increasing in these three periods, the degree of dispersion among different patches is high or the degree of landscape fragmentation is high, the interference intensity of human activities tends to increase, and the connectivity of the landscape pattern tends to be poor. On the other hand, the general trend of index of aggregation, mean closest distance, index of dispersion, index of diversity and index of evenness were going up, implying more fragmented in landscape pattern, greater human impacts, worse stability of structure and poorer self-adjustment, which would further impose restrictions on sustainability and biodiversity of Fuxian Lake basin.

## IV. Conclusions and Discussions

### A. Conclusion

Based on the remote sensing image date of Fuxian Lake basin in 1980, 1995, 2005 and 2015, this paper built a dynamic model of land use and made use of Fragstats4.2 software to analyze the change of land use and the disparities of landscape pattern indexes, and the results were elaborated as the following.

From the perspective of transfer of landscape in land use, water was a long-term high-quality landscape type, followed by farmland and forest, and grassland inferior to the former two, revealing that the land use was still in a period of development, and the degree of aggregation of land use was gently intensifying. Apart from water area, the roll-in and roll-out amount exhibited a globally upward trend. Further explained from the amount of conversion that the highest roll-out amount during the three periods was farmland, the next was the roll-in amount of grassland, the roll-out amount of forest followed, and the last was the roll-in amount of construction land. Meanwhile, compared with the other two periods, the time spanning from 2005 to 2015 showed a more dramatic change in landscape change.

From the transformation of landscape pattern of land use, the area of water had little alteration. Conversely, the land use of construction extended towards all directions with a concentration of density, and the addition of it was mainly attributed to the occupation of farmland. What's more, the exchange between forest and grassland was perceptible. Taking the geographical position into consideration, the landscape change of land use in the northern part was significantly obvious than the south, and the western coastal area than the east. In the north, it mainly showcased a change of construction land and farmland. Therefore, the changes of land use in landscape types in the western coastal areas were predominantly manifested in the exchange of forest and grassland, the reclamation of construction land for farmland and the conversion of farmland to grassland and forest so as to improve the environment around the lake.

From the perspective of landscape pattern index, the number of patches in Fuxian Lake basin has been increasing in the past 35 years, and the distribution among the patches is relatively discrete, the mutual interference among the landscape patterns is small, the land use is rich, the fragmentation is serious, and the dominant degree of the main landscape is decreasing. The main reason lies in the large-scale destruction of cultivated land, the reduction of the complexity of cultivated land landscape type, the increasing degree of fragmentation, and the increasing human disturbance to the landscape pattern of Fuxian Lake Basin Investigated from the aspect of annual average of change, the number of patches kept multiplying, the use of land were becoming plentiful, the mutual interference between the landscape patterns was small, the degree of discrete between different patches was strong or the degree of fragmentation of patches was high, the intensity of human interposition tended to grow larger, and the connectivity between landscape patterns were gradually deteriorating as poor connection between different landscapes, all of which imposed a certain degree of constriction to the sustainable development and biodiversity of Fuxian Lake basin.

### B. Discussion

Protection measures of Fuxian Lake basin should be strengthened. More attention should be paid on the landscape change of the northern and western coast of the basin. The conflicts between construction land and farmland are meant to be well-dealt. The destruction and fragmentation degree of farmland should be reduced. Meantime, reducing the development of unused land and improving the ecological environment of the area should be highlighted.

The vulnerability of landscape pattern can spatially reflect the vulnerability of the basin, unclothing the relationships among spatial distributions of landscape and human activities, but the landscape pattern index still cannot fully explain the vulnerability. In the terms of interruption, the weight and valuing of different indexes and valuing for vulnerability are not perfectly scientific as well. Thus, the next study focus is to evaluate the function of ecosystem service by combing the heterogeneity of landscapes, human activities and influence of land use.

1. The final results of this research can provide theoretical support to the protection and rebuilding of the ecological environment, and sustainable exploitation of land resources. To better mirror the terrain effect on land use, it is necessary to further improve the existent index of shape and diversity in the future studies. Simultaneously, a quantitative analysis of relationships between dynamic revolution of landscape pattern and deviations of time and space is suggested to conduct in order to achieve the final goal of balanced and sustainable development in social economy and ecological environment.

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