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Study on Landscape Pattern Evolution of Ecological-Living-Industrial Land in Plateau Mountainous Area: A Case Study of Yuxi City, Yunnan Province

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Abstract**—**The coordination and development of ecological-living-industrial land uses are the premise foundations for the formulation and implementation of the current land space planning, and more attention should be paid to plateau mountainous areas. This research is based on spatial analysis technology and landscape pattern index method taking Yuxi city, a typical mountainous plateau as the research area. By using relevant software such as ArcGIS10.5, Fragstats 4.2 and the four remote sensing images of Yuxi city in 1980, 1995, 2005 and 2015, the temporal-spatial evolution and differentiation pattern of ecological-living-industrial land applications have been discussed. The research results show that: (1) From the perspective of land use type change, ecological land of Yuxi city has been the main source of land from 1980 to 2015, which totally occupies more than 78%. During this period, the spatial structure of the ecological-living-industrial land changed significantly, namely, the living land. Its land area increased significantly from 0.83% of the total area in 1980 to 1.25% in 2015, the change range of ecological land and industrial land is relatively small. (2) In terms of land use landscape pattern transfer matrix, from 1980 to 2015, the industrial land and ecological land in Yuxi city have been gradually transferred to living land. (3) In the aspect of landscape pattern changes, various landscape pattern indexes of Yuxi city indicate that the fragmentation degree of landscape pattern of the ecological-living-industrial land in this region is increasing. The degree of agglomeration goes down, and the landscape types have changed from being relatively simple to relatively rich. The landscape is more diverse, but the patch size is uneven, meanwhile, the integrity of the ecological space is destroyed.

Keywords**—**Ecological-living-industrial land, spatio-temporal evolution, landscape pattern, plateau mountainous area.

I. Introduction

As human living space, land is the carrier of social and economic development [1]. Since the 1990s, land use/ cover change (LUCC) has become an important mean to study earth surface cover [2], [3]. As the contradiction between supply and demand of land use intensifies, the extensive urbanization land use model in China will not be sustainable in the long term. Guided by the concept of sustainable development and ecological civilization, China's land development, which is oriented by economic production functions, has gradually shifted to the coordinated use of land with three main functions [4] (production, living and ecological functions), forming the so-called ecological-living-industrial land [5]. The study of ecological-living-industrial land is the basis of land use/coverage planning and arrangement, which is conducive to the orderly, moderate and sustainable development and utilization of land space, and is also extremely important for strengthening the governance of land space planning [6]. Since the 18th National Congress of the Communist Party of China (CPC), the concept of "ecological-living-industrial land" has been put forward, namely, "promoting intensive and efficient production space, livable and moderate living space, beautiful landscape and beautiful ecological space", and "production, life and ecology" [7]. The Third Plenary Session of the 18th CPC Central Committee adopted the Decision of the CPC Central Committee on Some Major Issues concerning Comprehensively Deepening the Reform, which further proposed the establishment of a space planning system and delineated the limits of control over the development of production, living and ecological space. The report to the 19th National Congress of the CPC made it clear that we should create a favorable environment for people's production, living and ecological development. Clarifying the characteristics and influencing factors of urban "ecological-living-industrial land" use structure has become the basic work for scientific land planning and optimization of land use layout [8].

At present, the relevant researches at home and abroad mainly focus on the connotation, classification and spatial pattern of ecological-living-industrial land. By establishing the functional classification system and identifying the functional space of "ecological-living-industrial areas", the functional space of "ecological-living-industrial areas" can be optimized to improve the efficiency of land use. On the basis of exploring the connotation of the ecological-living-industrial space theory of "production-life-ecology", Jilai et al. established the classification and evaluation system of ecological-living-industrial land space and revealed the pattern and change characteristics of China's three living space from 1990 to 2010 from a macro perspective [9]; Hongqi et al. reflected the "ecological-living-industrial land" functions of land on the national scale, taking the main function of land as the starting

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point, taking other functions into consideration, and incorporating the concept of ecological land, he built a classification system of "ecological-living-industrial land" to coordinate production, life and ecological land space [10]. Rushan et al. analyzed the spatial function pattern of the "ecological-living-industrial land" of the Jianghuai urban agglomeration from different scales to reveal the different law of the functional types of the land space [11]. Qiuying et al. took the space utilization quality of "ecological-living-industrial land" as the assessment index, and used comprehensive evaluation method to analyze the characteristics of the comprehensive evaluation index of land space utilization quality at the national level and the provincial level [12]. However, relevant researches mainly aimed at urban economically developed areas and the landscape pattern [13], the form and connection of the land use in relatively backward areas, especially the plateau mountainous areas, have not been further studied [14]. As an important guarantee of national ecological security [15], mountainous area is the main battlefield of ecological civilization construction and the ecological barrier of social and economic development in plain area [16]. China is a mountainous country, with mountainous areas accounting for more than 70% of the total land area [17]. In order to carry out "rural revitalization" and "coordinated regional development" policy, the focus, difficulties and solutions are all centered on the mountainous areas. Therefore, it is helpful to implement the land space planning, promote the sustainable development of the plateau mountainous area and discuss the structure and layout of the land use and the temporal and spatial evolution of the plateau mountainous area [18].

With the steady implementation of the "One Belt and One Road" national strategy, Yuxi city is considered as the gateway and hub of south and southeast Asia, the leader of ecological civilization construction and the sub-core of central Yunnan city cluster. Its land layout is not only related to the sustainable development of local economy, but also an important guarantee for the land resource security and ecological civilization construction in the whole central Yunnan city cluster and the national gateway hub region. This project takes the landscape pattern of ecological-living-industrial land in Yuxi city as the research's object. According to the research purpose and the regional ecological function nature as well as the image quality of remote sensing image, the relevant data provided by geospatial data cloud and the TM/ETM remote sensing image data of the research area in 1980, 1995, 2005 and 2015 were selected. For the land use of Yuxi, the temporal and spatial evolution characteristics of land-use, such as landscape transfer and index of landscape pattern have been studied by using ArcGIS 10.5 and Fragstats 4.2 software, remote sensing image interpretation and GIS spatial analysis technology etc. It provides theoretical and practical basis for the sustainable development of Yuxi city's coordinated economic, social and ecological construction. It also provides reference and guidance for the rational utilization and scientific planning of land in the same scale area.

II. Materials and Methods

A. Overview of the Research Area

Yuxi is a prefecture-level city in the central part of Yunnan Province, the geographical coordinates are between 23°19'-24°53'N and 101°16'-103°09'E. It is the nearest city to the provincial capital city, Kunming. At the same time, Yuxi is located in the important connecting part of Kun-Man and Kun-He economic belts. It has the function of collecting and distributing the central city of the provincial capital, connecting southern Yunnan and radiating Southeast Asia. It is the distributing and processing "hinterland" of Yunnan Province for Southeast Asia and South Asia to implement the strategy of "going out". Its geographical location is not only facing the gateway hub of South and Southeast Asia, the leader of ecological civilization construction and the sub-core of central Yunnan city cluster, but also relates to the sustainable development of local economy, and is an important guarantee for land resource security and ecological civilization construction of the whole central Yunnan city cluster and national gateway hub region.

Yuxi's economic aggregate ranks the third in Yunnan Province, its total fiscal revenue and local fiscal revenue rank the second in Yunnan Province, and its per capita net income of farmers ranks the first in Yunnan Province [19]. It is one of the regions with strong comprehensive economic strength in Yunnan Province. It has a good industrial development foundation. The pillar position of "Two tobacco" and supporting industries has been continuously consolidated and improved, the mining and electricity industry has been built into a new pillar industry, the tourism and cultural industries have developed rapidly, and the characteristic economic development of counties has been accelerated. Counties and districts have initially formed pillar industries with their own characteristics, and their local fiscal revenue has exceeded 100 million Yuan. Yuxi has made brilliant achievements in various industries and gone out of the way of industrial development which is different from other cities and states in Yunnan. It has a strong comparative advantage in the whole province.

B. The Establishment of the "Ecological-Living-Industrial Land" Classification System

"Three living land" is the abbreviation of "production, life and ecology land", and it refers to land for production, life and ecology. By referring to a large number of relevant literatures [20]-[22] and combining the current situation of land use in Yuxi city, from the perspective of ecological, productive and living functions, the classification of ecological-living-industrial land is converted to the classification of land use status of Chinese Academy of Sciences, and the classification table of ecological-living-industrial land in Yuxi city is obtained, Table I.

C. Data Sources and Processing

According to the purpose of the study, the ecological function nature of the study area and the image quality of the remote sensing image, the relevant data provided by the geospatial data cloud and the TM/ETM remote sensing image

data of the study area in 1980, 1995, 2005 and 2015 (the ground resolution is 30 m × 30 m) are selected, and the telemetry map is derived from the geospatial data cloud website and is supplemented by data related to the research area.

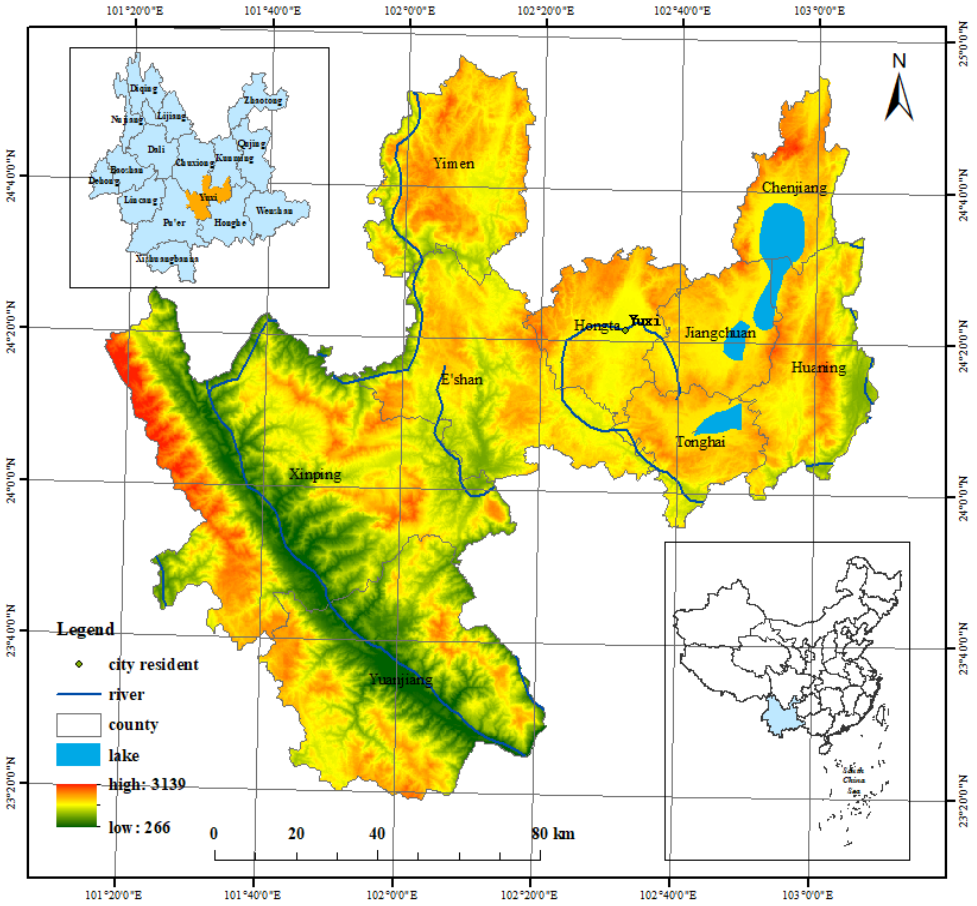

Fig. 1 Location of the study area

TABLE I
CLASSIFICATION OF ECOLOGICAL-LIVING-INDUSTRIAL LAND AND LAND USE STATUS IN YUXI CITY

The first class of three land uses	Ecological-living-industrial land	Chinese Academy of Sciences land Classification
Land for industrial	Land for agricultural production	11 paddy field 12 the dry land
	Land for industrial and mining production	53 other construction land
Land for living	Urban living land	51 urban land use
	Rural living land	52 rural settlement
Ecological land	Green by ecological land	21 forestland 22 shrub land 23 opening 24 other woodland 31 high coverage grassland 32 medium coverage of grassland 33 low coverage grassland
	Aquatic ecological land	41 graff 42 lakes 43 reservoir pits 46 on beaches

Referring to topographic map, land use map and other auxiliary information, the use of ENVI5.3 software after striping removal processing, radiation correction, geometric correction, image stitching and clipping, image enhancement and other image processing means, the supervised classification method is used to interpret remote sensing images and modify the unsupervised classification results with the help of other relevant data information. Combining supervised classification and manual visual interpretation to obtain land use classification data, image pre-processing, spatial analysis, and calculation and raster data unit calculation are reclassified. After referring to the land use classification system at home, abroad and the land use status of the research area, considering the possible interpretation ability of remote sensing images and the purpose of this study, the land use types in Yuxi city are divided into three types; namely, production, life and ecology, from the perspective of ecological, production and living functions. The accuracy of the confounding matrix is more than 75%, which meets the requirement of discriminant classification error accuracy. At last, ArcGIS10.5 and

FragStats4.2 software were used for data format conversion, stacking analysis, cutting calculation and other basic processing, the land use data information and landscape pattern index of the study area were obtained, and the spatial distribution data of land use landscape types in the four stages of the study area were obtained.

D. Research Methods

Changes in Land Use Types

The change amplitude of land use is mainly reflected in the change of total area of different land use types. By analyzing the change of total area of different land use types in the study area [23], [24], the overall trend of land use change can be clearly understood [25].

The regional difference of landscape change rate can be reflected by a single land use dynamic attitude model. The formulas are as follows [26]:

Dynamic Attitude of Single Land Use Type

A single dynamic land use attitude can quantitatively express the speed of a certain land use change and effectively predict the future land use change trend [27].

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where, K is the dynamic attitude of a certain land use type during the research period, Ua and Ub are the quantity of a certain land use type at the beginning and end of the study, and T is the research period. When T is set as year, K is the annual rate of change of a certain land use type in the study area.

Dynamic Attitude towards Comprehensive Land Use

The dynamic attitude of regional comprehensive land use is used to describe the speed of regional land use change, but also to describe the change of spatial form, highlighting the intensity of regional land use [28].

$$LC = \left[\frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{\sum_{i=1}^{n} LU_i} \right] \times \frac{1}{T} \times 100\% \quad (2)$$

where, LC is the dynamic attitude of comprehensive land use type; LU_i is the area of type i in the first phase (hm^2); ΔLU_{i-j} is the area of land use type i converted to type j at the end of the study(hm^2); T is the study period.

Land Use Landscape Pattern Transfer Matrix

Transfer matrix is the main quantitative method to carry out the research on the number and direction of mutual transformation among landscape types, which can reflect the structural characteristics of landscape changes and the direction of transfer among different types [29]. With the help of ArcGIS 10.5 platform, the area ratio and dynamic attitude of various land use landscape types were calculated, and the land use transfer matrix for three periods was made. The mathematical form of the transfer matrix can be expressed as [30]:

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix} \quad (3)$$

where, P is the area; N is the number of landscape types

Landscape Index

View index is considered as an effective quantitative tool to study the dynamic changes and functions of land use landscape pattern, which can quantitatively describe the changes of spatial structure and pattern of landscape [31]. Combining with the evolution of landscape pattern of ecological-living-industrial land in Yuxi city, this study analyzed landscape pattern from two dimensions, landscape type and landscape level, by selecting indexes that are widely used at home and abroad and whose formula has a clear meaning. Firstly, percent of landscape (PLAND), number of patches (NP), patch density (PD), largest patch index (LPI), and edge density (ED) and mean patch size (MPS) were selected at the type level. Landscape level from the perspective of landscape heterogeneity number of patches (NP), mean patch size (MPS), contagion index (CONTAG), spread and parallel index (IJI), landscape shape index (LSI), fractal dimension (MFRAC), diversity index (SHDI) and evenness index (SHEI), a total of eight indicators, were discussed in Yuxi city from 1980 to 2015 years junior changes of land use landscape level. All indicators were calculated by Fragstats 4.2 software, and the calculation formula of the above landscape indicators and its ecological significance are shown in [32].

III. Results and Analysis

A. Evolution Characteristics of Landscape Structure of Ecological-Living-Industrial Land

The composition of area percentage directly reflects the spatial structure of the ecological-living-industrial land in the study area (Table II). This study makes a comparative analysis of the spatial structure changes of the ecological-living-industrial land in Yuxi city in different periods.

The comparative analysis of Table II shows that the research area is dominated by ecological land. From 1980 to 2015, the ecological land area has accounted for more than 78% of the total area of the research area; the second is industrial land, accounting for about 20% of the total area of the region. The living land only accounts for about 1% of the total area.

The data show that the spatial structure of the ecological-living-industrial land in Yuxi has changed significantly, from 1980 to 2015; the area of the living land has increased significantly. In 1980, the area of the living land only accounted for 0.83% of the total area of the region, and in 2015, the area has increased to 1.25%. However, the change range of

ecological land and industrial land is relatively small. Mainly due to the policy-driven population growth and urbanization, urban expansion and rural residential construction are dominated by occupied farmland, which leads to the continuous decrease of cultivated land resources and the conversion of ecological land and industrial land into living land. Therefore, the living land has increased greatly during this period.

TABLE II
SPATIAL STRUCTURE OF THE ECOLOGICAL-LIVING-INDUSTRIAL LAND IN YUXI FROM 1980 TO 2015

Land use types	1980		1995		2005		2015	
	Area (hm^2)	The proportion (%)	Area (hm^2)	The proportion (%)	Area (hm^2)	The proportion (%)	Area (hm^2)	The proportion (%)
Land for industrial	301518.89	20.11	296529.90	19.78	305465.81	20.37	298302.59	19.89
Land for life	12392.82	0.83	13021.83	0.87	15835.12	1.06	18774.88	1.25
Ecological land	1185492.78	79.06	1189852.76	79.36	1178103.56	78.57	1182327.03	78.85

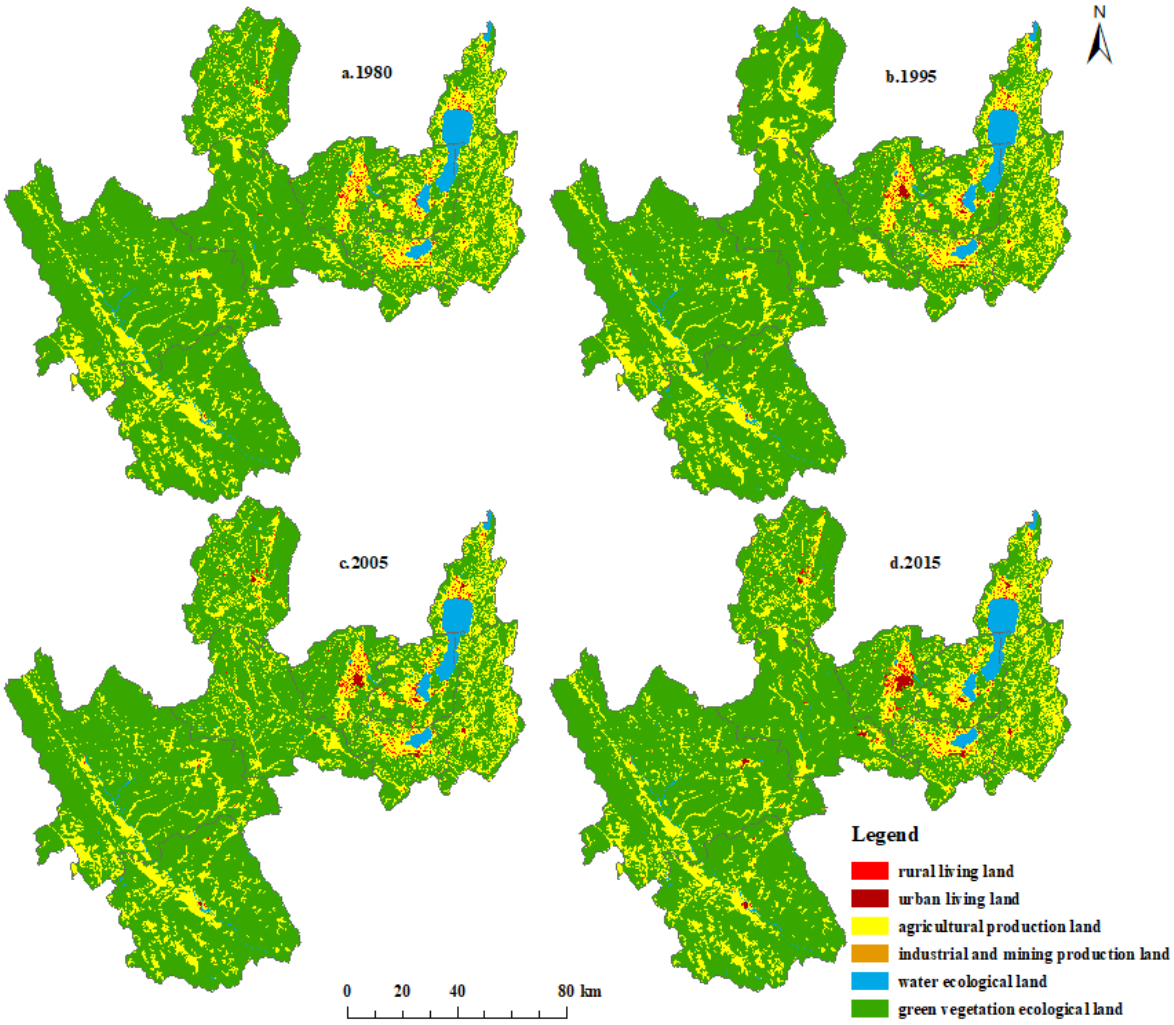

Fig. 2 Structure of the ecological-living-industrial land in Yuxi city from 1980 to 2015

Fig. 2 shows that from 1980 to 2015, the research land for production represents a significant share, and the involved land for agricultural production is all over the city, but mainly concentrated in the northeast and southwest. Because of the natural geography and social economic conditions of Yuxi city, less area of land for industrial and mining production is mainly distributed in northeast of the city. In general, Yuxi is high in the northwest, low in the southeast and complex in terrain. In the east and north of Yuxi, there are some large fault collapse basins and abundant water resources, which can meet the need of daily life and production. In addition, the industrialization and urbanization development in the northeast is relatively concentrated. Driven by the orientation of policy, and rapid development in urbanization, the city expands continuously, and the social and economic conditions are relatively superior. Therefore, the living land is mainly

distributed in the northeast of the city.

Fig. 2 illustrates that the living land for urban life is gradually expanding to the south area, it is because the flat terrain in southeastern is convenient to be facilitated and exploited. Furthermore, the increasing of population demands more construction land, and under the guidance of policy in the rapid advance of urbanization, life land scale is gradually expanding to southward. The rural living land is mainly distributed in the northeast of the city and the area has been expanded. This is because with the demand of social and economic development, people have gradually increased the degree of land development and utilization, and human activities have gradually deepened the impact on the land ecosystem. The ecological land occupies a large proportion, among which the green land is distributed all over the city, but the most is distributed in the central area of the city, and the water area ecological land is mainly concentrated in the northeast part of the city, which is determined by the topography and landform of Yuxi city itself.

B. Characteristics of Dynamic Change of Land Use

Temporal Changes

Based on the four phases land use/cover data, the land use change model and dynamic attitude model, this paper analyzed and discussed the temporal dynamic change in the quantity structure of three land uses in Yuxi city from 1980 to 2015 according to Table III. The land used for agricultural production and rural living decreased, while the rest increased. The land used for agricultural production decreased by 352.63 hm^2. From 1995 to 2005, the land used for production and living increased greatly, but the ecological land decreased rapidly. Except for the reduction of green land by 1198.34 hm^2, all other items increased. From 2005 to 2015, with the rapid social and economic development, the land used for production decreased, mainly by 1025.98 hm^2 for agricultural production, while the land used for living maintained the growth trend, ecological land also increased, and green land ecological land increased by 418.44 hm^2. The land used for industrial and mining production increased significantly, with an annual change rate of 21.2095%. The land used for urban living changed significantly, and the land used for rural living, green land and water ecological land remained relatively stable. In general, from 1980 to 2015, the land for production decreased the land for living increased, and the land for ecological use decreased in Yuxi.

TABLE III
ANNUAL DYNAMIC CHANGES OF THE ECOLOGICAL-LIVING-INDUSTRIAL LAND IN YUXI CITY FROM 1980 TO 2015

Change the type	Period of time	Agricultural Land for production	Land for industrial and mining production	Urban living land	Rural living land	Green by ecological land	Aquatic ecological land
Change the amount (hm^2)	1980-1995	-352.63	20.03	120.46	-78.52	269.56	21.10
	1995-2005	868.53	25.06	74.49	206.84	-1,198.34	23.42
	2005-2015	-1,025.98	309.65	218.38	75.59	418.44	3.91
Single dynamic attitude (%)	1980-1995	-0.1173	2.2033	10.8804	-0.6958	0.0235	0.0570
	1995-2005	0.2941	2.0717	2.5564	2.0463	-0.1040	0.0627
	2005-2015	-0.3375	21.2095	5.9687	0.6208	0.0367	0.0104
Comprehensive dynamic attitude (%)	1980-1995			0.1195			
	1995-2005			0.2342			
	2005-2015			0.2174			

The comprehensive dynamic attitude value can describe the dynamic attitude of land use types in Yuxi [33]. The dynamic characteristics of land use time can be divided into four types: 0-3% (extremely slow change type); 4-12% (slow variation); 13-20% (rapid change); 21-24% (sharp change type) [34]. As shown in Table III, the comprehensive dynamic attitude of Yuxi city was 0.1195% from 1980 to 1995, 0.2342% from 1995 to 2005, and 0.2174% from 2005 to 2015. Therefore, Yuxi city has a relatively slow change type compared with other places in the three periods from 1980 to 2015, so it is judged that the spatial change of the ecological-living-industrial land in Yuxi city is slow.

It can be seen from Table III that the comprehensive dynamic attitude of Yuxi changed most obviously from 1995 to 2005, with the comprehensive dynamic increasing continuously and increasing greatly. From 2005 to 2015, the comprehensive dynamic slowed down to a small extent. Because Yuxi city is located in central Yunnan Province, southwest mountainous area, when compared with the national, the development level is still relatively backward Besides, there are unreasonable industrial structure, backward education, low labor quality, and ecological deterioration, so the dynamic land use type of Yuxi in 1980-2005 three periods to present the above changes.

Regional differences

On the basis of the formation of physical geographical conditions, the research area is divided into different spatial regions according to the research area and purpose. The spatial differences and morphological characteristics of each research area can be intuitively analyzed.

According to Fig. 3, from the overall spatial structure, in Yuxi city, ecological land > industrial land > living land, and the proportion of different land use types is different. The industrial land is mainly distributed in the northeastern, southwest and north part of Yuxi city, and it tends to move to the northwest. In general, the industrial land in Yuxi city is scattered. The living land is mainly concentrated in the northeastern central area of the study area, which is dotted, scattering and spreading to all sides. The ecological land is distributed all over the study area in a planar pattern, shifting

from the central zone to the southwest and northeast marginal zone.

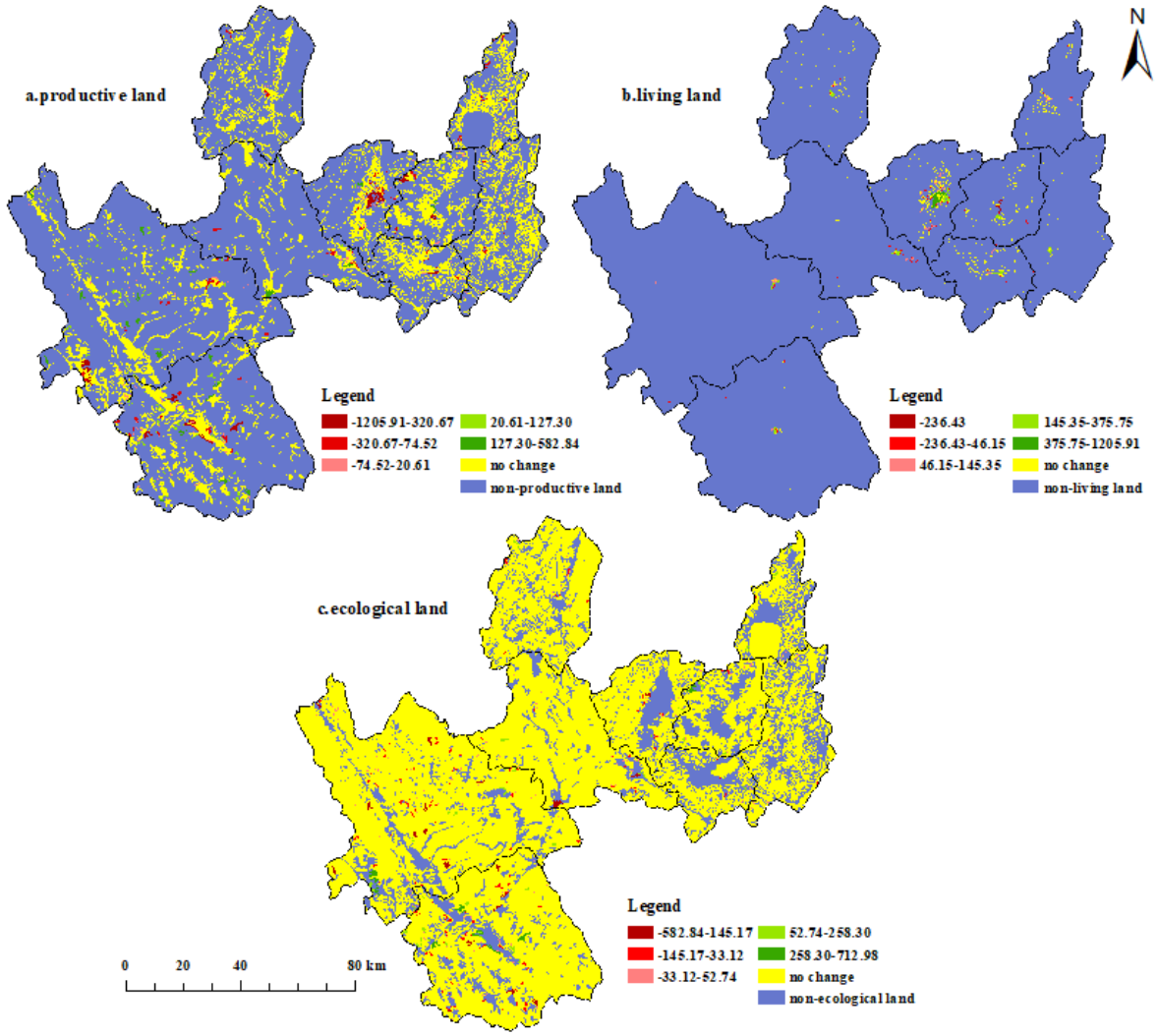

Fig. 3 Structure of ecological-living-industrial land from 1980 to 2015

The location and the distribution of the land transfer is closely related to two factors: the nature and the society. The land in east north and northeast of Yuxi city is good for production and living due to the relatively superior natural conditions, social economic conditions, perfect infrastructure and convenient transportation. The perfect match in heat and water resources, in combination with gently topography, provides advantages for the development and utilization of the economic activities of production and life. The gradual migration of industrial land to the north is due to the improvement of infrastructure, the support of government policies, human transformation of natural environment and technological progress.

C. Landscape Transfer Characteristics of Ecological-Living-Industrial Land

The results of the transfer matrix in Tables IV-VI show that from 1980 to 2015, the industrial land and ecological land in Yuxi city have been transferred to the living land in large quantities. Specifically, the land used for agricultural production and the land used for green land were transferred significantly, and the amount of land transferred between them varied greatly. The difference of the mutual conversion amount was as high as 263.68 hm^2. The land for urban living has increased significantly, which is the transfer of land for agricultural production. The land for industrial and mining production has also increased significantly, mainly occupying the land for agricultural production and green ecological land. Rural living land area increased, mainly from agricultural production land and green into ecological land. In ecological land, the area of green land is reduced, and the land is mainly converted to agricultural production land and industrial and mining production land. The ecological land in the water area

increased slightly, and it was mainly transferred from agricultural production land and green land to ecological land.

It can be seen from Table IV that the land for production is decreasing while the land for living and ecological use is increasing. Among them, the land used for agricultural production and rural living is decreasing, with the most prominent decrease of the land used for agricultural production, from 300609.89 hm^2 in 1980 to 295320.48 hm^2 in 1995, by 5289.41 hm^2, while other types of land are increasing. The largest increase is green ecological land, which increased by 4043.45 hm^2 from 1148487.82 hm^2 in 1980 to 1152531.26 hm^2 in 1995. From 1980 to 1995, in the early stage of reforming and opening up, the proportion of industry and commerce and the tertiary industry gradually increased, and all regions actively invested in industrial production construction, urbanization developing, thus the farmland was occupied and the farmland reduced, and a large amount of land was used for industrial production construction, so the land for agricultural production was greatly reduced.

TABLE IV
TRANSFER MATRIX OF ECOLOGICAL-LIVING-INDUSTRIAL LAND IN YUXI CITY FROM 1980 TO 1995 (HM^2)

1980	1995					
	Land for agricultural production	Land for industrial and mining production	Urban living land	Rural living land	Green by ecological land	Aquatic ecological land
Land for agricultural production	272053.63	0.09	50.67	660.78	22299.72	255.60
Land for industrial and mining production	172.71	908.91	0.00	0.00	127.80	0.00
Urban living land	1529.28	0.00	1056.42	297.99	30.24	0.00
Rural living land	268.47	0.00	0.00	9752.67	86.76	0.00
Green by ecological land	26470.25	0.00	0.00	574.29	1125312.31	174.42
Aquatic ecological land	115.56	0.00	0.00	0.00	630.99	36574.94

TABLE V
TRANSFER MATRIX (HM^2) OF THE ECOLOGICAL-LIVING-INDUSTRIAL LAND IN YUXI CITY FROM 1995 TO 2005

1995	2005					
	Land for agricultural production	Land for industrial and mining production	Urban living land	Rural living land	Green by ecological land	Aquatic ecological land
Land for agricultural production	265554.14	12.96	7.92	108.54	38278.98	43.29
Land for industrial and mining production	188.28	1145.88	0.00	0.00	125.82	0.00
Urban living land	744.84	0.00	2906.01	0.00	0.00	8.01
Rural living land	1275.12	39.06	0.00	9934.65	927.43	0.00
Green by ecological land	27360.73	11.52	0.00	64.71	1112729.33	381.60
Aquatic ecological land	197.37	0.00	0.00	0.00	469.71	36888.59

TABLE VI
TRANSFER MATRIX OF ECOLOGICAL-LIVING-INDUSTRIAL LAND IN YUXI CITY FROM 2005 TO 2015 (HM^2)

2005	2015					
	Land for agricultural production	Land for industrial and mining production	Urban living land	Rural living land	Green by ecological land	Aquatic ecological land
Land for agricultural production	268762.30	152.55	303.93	953.73	23431.17	142.38
Land for industrial and mining production	1613.11	847.71	29.43	17.19	2049.08	0.00
Urban living land	1965.78	248.22	3097.26	185.40	326.88	19.17
Rural living land	1378.17	169.11	228.24	10648.78	494.19	13.68
Green by ecological land	30023.94	42.39	0.00	330.39	1113911.41	424.17
Aquatic ecological land	262.53	0.00	0.00	40.77	335.16	36956.27

It can be seen from Table V that the land used for production and living is increasing, while the ecological land is decreasing. Among the land used for production, the land used for agricultural production increased the most, from 295,320.48 hm^2 in 1995 to 30,4005.83 hm^2 in 2005, by 8685.35 hm^2; among the living land, rural living land increased the most, from 1,0107.89 hm^2 in 1995 to 12,176.2 hm^2 in 2005, by 2,068.36 hm^2. In the ecological land, the ecological use of green land decreased by 11983.38 hm^2 from 1152531.26 hm^2 in 1995 to 1140547.8 hm^2 in 2015. With the continuous development of economy and the progress of science and technology, the output of agricultural production has been greatly increased, while the accelerated process of industry and urbanization has destroyed the ecological environment. Meanwhile, with the continuous growth of population and economy, the large-scale land development has resulted in the conversion of a large amount of ecological land into living and industrial land; great changes have taken place in the structure of urban land, with ecological land reducing and land of living and production increasing.

It can be seen from Table VI that the land for production is decreasing while the land for living and ecological use is increasing. Among the industrial land, agricultural production decreased by 10259.77 hm^2 from 304005.83 hm^2 in 2005 to 293746.06 hm^2 in 2015, and industrial and mining production land increased by 3096.54 hm^2 from 1459.97 hm^2 in 2005 to

4556.52 hm^2 in 2015; among the living land, the urban living land increased a lot, from 3658.85 hm^2 in 2005 to 5842.70 hm^2 in 2015 by 2,183.85 hm^2. In general, the increase of green land is more prominent, from 1140547.89 hm^2 in 2005 to 1144732.30 hm^2 in 2015 by 4184.41 hm^2, and the decrease of agricultural land is more obvious. Due to the progress of technology, the efficiency in industrial and agricultural production promotes the land utilization of unit land area. The national policy guidance and support and people's rising awareness in environmental protection makes the ecological land use increase and industrial land reduce, and land for the continuous development of urbanization makes life demand in tension, so the life land will continue to increase.

D. Landscape Pattern Change

Type Level Variation

In this paper, six indicators, namely PLAND, NP, PD, LPI, ED, and MPS, were selected at the type level to study the variation of the three land types in Yuxi from 1980 to 2015.

TABLE VII
YUXI STROKE OF THE LAND IN 1980-2015

Land use types	year	PLAND/%	NP	PD/·10-2hm-2	LPI /%	ED /m·hm-2	MPS /hm2
Land for production	1980	20.13	709	0.0473	2.44	5.6638	425.75
	1995	19.94	637	0.0425	2.33	5.4089	469.39
	2005	20.32	797	0.0532	2.30	5.9403	382.27
	2015	19.86	752	0.0502	1.76	5.8114	395.88
Land for life	1980	0.81	149	0.0099	0.04	0.3915	81.65
	1995	0.87	128	0.0085	0.11	0.3857	101.54
	2005	1.08	155	0.0103	0.13	0.467	104.65
	2015	1.24	143	0.0095	0.27	0.4776	130.52
Ecological land	1980	79.06	30	0.0020	78.87	5.5003	39509.60
	1995	79.19	34	0.0023	78.98	5.2242	34921.05
	2005	78.60	33	0.0022	78.39	5.7657	35709.86
	2015	78.90	34	0.0023	78.70	5.6359	34792.60

It can be seen from Table VII that from 1980 to 2015, the landscape types of Yuxi city were mainly ecological landscape. However, with the economic development and increasing human activities, the overall ecological land area showed a downward trend, while the living land area gradually increased and the industrial land area decreased. The overall trend of productive land is increasing, the maximum patch area and the MPS are decreasing, and the PLAND fluctuates around 20%, indicating that human activities have gradually expanded the scope of productive land; the number and density of patches in the living land fluctuated, and the proportion of patch type area, maximum patch area index, ED and MPS showed an overall trend of growth, indicating that with the development of urbanization, people's demand for living land increased continuously and living space became larger and larger. The number of ecological land patches is on the rise, the PLAND fluctuates around 79%, the PD gradually increases, and the maximum patch area is basically unchanged. Due to human intervention, the MPS is decreasing, which destroys the integrity of ecological space. In a word, with the increase of population and activity space, people's living land is expanding and expanding to other lands.

Landscape Horizontal Change

From the perspective of landscape heterogeneity, eight indicators, namely, NP, MPS, CONTAG, IJI, LSI, MFRAC, SHDI and SHEI [35] were selected to analyze the changing process of landscape pattern of the ecological-living-industrial land in Yuxi.

With the advancement of urbanization and rapid economic development, the increasing demand of land for people also increases accordingly, which leads to the transfer and change of ecological, living and productive land area. The main reason that causes the change of landscape level index is the disturbance of human activities.

Fig. 4 shows that the NP in Yuxi increased from 1980 to 1995, decreased from 1995 to 2005, and increased again from 2005 to 2015. Generally speaking, the NP and MPS in Yuxi city show a trend of fluctuation and increase, which indicates that the fragmentation degree of landscape pattern in Yuxi city is increased due to the influence of human activities. With the acceleration of urbanization, various landscape lands are divided significantly and the degree of agglomeration decreases. The significant decrease of CONTAG indicates that the landscape pattern of Yuxi has strong connectivity and relatively unified spatial distribution. The continuous and steady increase of IJI reflects that the spatial landscape pattern distribution tends to be concentrated in Yuxi. The fluctuating and rising trend of LSI indicates that the landscape pattern of Yuxi city tends to be complicated. At the same time, it also indicates that the stability and dominance of the landscape in Yuxi city decrease. This is mainly because with the development of economy and society, other land has been continuously developed and utilized, leading to a large reduction in reserve land resources. The MFRAC reflects the fluctuating trend of the availability and irregularity of landscape forms, from 1980 to 2015, the MFRAC of Yuxi city first increased, then decreased and then increased, showing an overall trend of increase, indicating that natural factors and human activities constantly and greatly destroy and disturb the landscape pattern. It also shows that during this period the total area of the land is increasing, the degree of dispersion and

division is increasing. With the rapid development of urban society, economy and the rapid increase of population, a large part of cultivated land has been destroyed and transformed into factories and towns, etc., and in order to improve the planting yield, the effective cultivated land area has been increased through the land renovation project carried out by artificial activities. As a result, MFRAC of Yuxi city is on the rise. SHDI and SHEI increased significantly from 1995 to 2005 but increased slightly from 2005 to 2015, and the increase of SHDI indicates that the complexity of landscape structure composition in Yuxi tends to increase, indicating that the landscape types of Yuxi city have changed from relatively simple to abundant, landscape types have increased with rising landscape fragmentation, and the dominance of urban construction land plaques has decreased. The increase of the SHEI indicates the uneven patch size in Yuxi city.

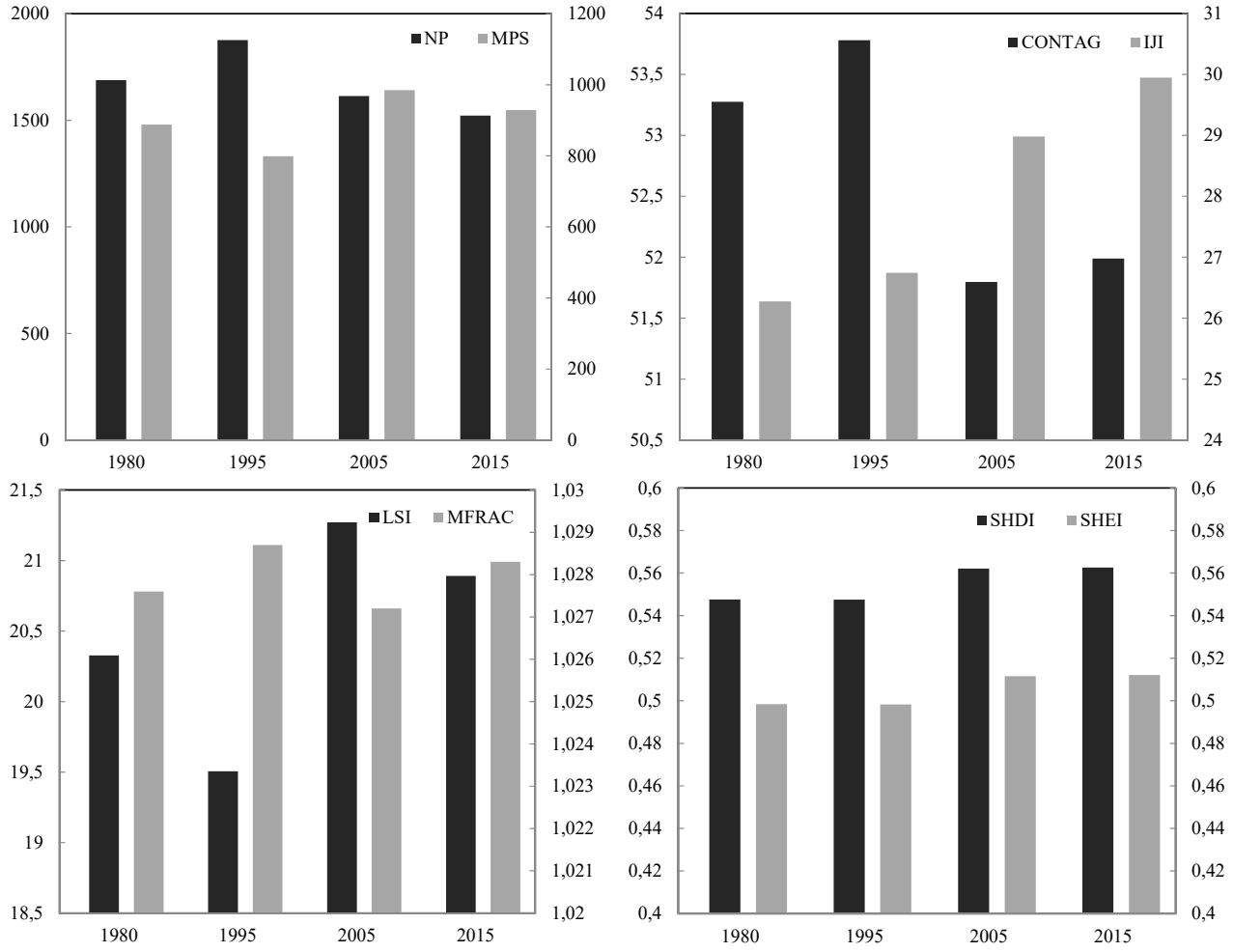

Fig. 4 Landscape Level index of Yuxi city from 1980 to 2015

IV. Conclusion and Discussion

This study takes Yuxi city as the research area and the landscape pattern of the ecological-living-industrial land in Yuxi city as the research object. Four phases of satellite remote sensing images were adopted in Yuxi city in 1980, 1995, 2005 and 2015. By using ArcGIS 10.5 and Fragstats 4.2 remote sensing image interpretation, interpretation technology and GIS spatial analysis technology, three methods of land use type dynamic change analysis, land use landscape pattern transfer matrix, landscape index selection and calculation were used to quantitatively analyze the evolution characteristics, functions and rules of the landscape pattern of ecological-living-industrial land in Yuxi city from 1980 to 2015.

From the perspective of spatial-temporal dynamic change of land use, the ecological-living-industrial land of Yuxi city has changed significantly, and the ecological land area of Yuxi city accounts for more than 78% of the total area of the study area. The second is industrial land, accounting for about 20% of the total area of the region. The living land only accounts for about 1% of the total area. From 1980 to 2015, the living land has undergone a significant change in spatial structure of the ecological-living-industrial land. From 1980 to 2015, the area of the living land increased significantly, which only accounted for 0.83% of the total area of the region in 1980 and increased to 1.25% in 2015. However, the change range of

ecological land and industrial land was relatively small. It is mainly manifested in the fact that a large number of ecological land and industrial land have been converted into living land due to the expansion of cities and towns and the occupation of farmland for the construction of rural residential areas.

From the perspective of the change of landscape pattern transfer matrix of ecological-living-industrial land, the concrete manifestation is that from 1980 to 2015, the industrial land and ecological land in Yuxi city have decreased significantly, while the living land has increased. This is mainly reflected in the significant decrease of agricultural production land and green covered ecological land, and the change of land transfer quantity of these two lands is also the largest, with the difference of mutual conversion amount as high as 263.68 hm^2. The land for urban living has increased significantly, which is mainly reflected in the occupation of agricultural production land. Land for industrial and mining production has also increased significantly, mainly occupying the land for agricultural production and green ecological land. Rural living land area increased, mainly from agricultural production land and green into ecological land. In ecological land, the area of green land is reduced, and the land is mainly converted to agricultural production land and industrial and mining production land. The ecological land in the water area increased slightly, mainly from agricultural production land and green land transferred to ecological land.

From the perspective of spatial-temporal dynamic changes of landscape pattern, the fragmentation degree of landscape pattern in Yuxi city increases, and the degree of agglomeration decreases. Therefore, the connectivity between landscape patterns is strong, and the spatial distribution tends to be uniform. The complexity of landscape structure composition in Yuxi tends to increase, which indicates that the landscape types in Yuxi change from simple to rich and the landscape types increase. The landscape type of Yuxi city is mainly ecological functional land. With the development of economy and increasing human activities, the area of ecological functional land is on the whole declining, the area of living functional land is gradually increasing, and the area of production functional land is on the whole decreasing. Natural factors and the destruction and interference of human activities make the landscape pattern of Yuxi city change constantly, and change greatly. However, human activities make the scope of production function land expand, and life function land expand and expand to other function land.

From 1980 to 2015, the landscape pattern of the ecological-living-industrial land in Yuxi city changed greatly under the dual action of natural factors and social and economic factors. From the perspective of the overall landscape pattern of Yuxi city, economic factors have become the main influencing factors for the evolution of landscape pattern of the ecological-living-industrial land in Yuxi city with the rapid development of human society, social. It is mainly manifested in the continuous growth of population and economy, large-scale land development, which leads to the transformation of a large number of ecological lands into living and industrial land, and the great change of urban land structure. In order to realize the sustainable development of the ecological-living-industrial land in Yuxi city, it is necessary to strengthen the development and arrangement of the landscape pattern of ecological-living-industrial land in Yuxi city to prevent the three living land from being occupied by disorderly development, to implement strict land planning management for urban, rural, industrial, mining and residential land to reduce its impact on landscape pattern fragmentation. In the future development of cities, the potential of land should be further explored, the intensive utilization of land should be continuously improved, and the functional land for ecological services should be protected and increased.

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