

Research on the RS-based landscape patterns of tourist cities using Guilin as an illustration

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Abstract. In China and beyond, Guilin is a well-known tourism destination. The city is home to numerous tourist attractions. By 2021, the area of forest land in the study area would account for the biggest proportion, according to the analysis of remote sensing data. The area of water and cultivated land shrank in comparison to 2000, and although the area of construction land expanded year over year, it indicated a decreasing tendency. The driving force analysis reveals that the protection and maintenance of landscape resources must be the primary focus of urban development if a sustainable tourism city is to be created. The study region's center urban area is primarily intended to safeguard natural resources and promote tourism, so the rate of expansion of the area used for building is declining. Guilin proposed the idea of creating two city centers, which successfully overcame the conflict between urban growth and environmental conservation, enhanced the study region's ecological conditions, and expanded the area of forested land. It is suggested to adhere to the policy of the development of the two urban centers by evaluating the historical development of Guilin City. The spatial interaction between various land uses should be fairly arranged with the aim of creating a landscaped city as part of the future development of Lingui New Area. Maximize the landscape resources of the center urban area, restrict the growth of the construction area in the central urban area, carry out micro-transformation on idle land in the city, create pocket parks and green spaces, and build rural tourism on agricultural land at the outskirts of the city.

Keywords: Landscape pattern, RS, GIS, Tourism City Guilin.

1. Introduction

Guilin is in the first group of Chinese historical, cultural, and tourist destinations. The urban region has numerous beautiful locations. It is a typical urban design for fusing a metropolis with a natural setting. A distinctive urban landscape plan has been shaped by various natural and human elements that have produced various urban impressions. A city's creation and growth can be examined from the angles of the humanities, the economy, and nature. In addition, the historical development of urban planning can be researched from the standpoint of landscape ecology. The dynamic shift in an urban landscape's pattern can highlight aspects of a city's historical growth [1], compile knowledge from those aspects of development, and offer helpful recommendations for future urban design.

Landscape ecology is a broad, multidisciplinary field of study. Landscape ecology was introduced to China, where it underwent a period of rapid development from the 1990s until the start of the twenty-first century [2]. Landscape pattern, ecological process, and their scale dependency are the focus of landscape ecology research and its main benefit [3]. Studying the urban landscape pattern is the key to revealing the characteristics of the urbanization process and serves as the foundation for an in-depth investigation of urban land use change [4]. Analysis of landscape patterns has been applied extensively in a variety of sectors, including ecology, geoscience, landscape design, and urban and rural planning. Landscape spatial structure analysis allows for the drawing of logical and scientific conclusions. Zhang Jiachen et al. classified the Qingdao coastal zone's susceptibility as mild vulnerability after analyzing the landscape layout of the city and assessing its ecological vulnerability [5]. By choosing 24 widely used landscape pattern indicators, Peng Jian et al. revised the Bao'an District of Shenzhen's land use classification. They discovered that the outcomes of several land use classification approaches varied when compared to those of other studies [6]. Ni Kaixuan integrated the scale theory with the landscape pattern index from the ecological belt southwest of Zhengzhou

and found that the two had a beneficial and efficient impact on the preservation and growth of the rural ecological pattern [7]. Guilin is used as the research subject in this study. It explores the characteristics and reasons for the changing landscape pattern in Guilin by analyzing remote sensing images taken in 2000, 2014, and 2021. It also provides scientific support for the establishment of a world-class tourism city, a national forest city, and an eco-tourism city in Guilin in the future.

2. Overview of the Study Area

In China and beyond, Guilin is a well-known tourism destination. It features a distinctive natural setting and a typical karst landform. It is situated in the midst of the northern end of the Guilin-Yangshuo Karst Basin, southwest of the Nanling Mountain System, and northeast of the Guangxi Zhuang Autonomous Region. It is situated at $24^{\circ} 15' 23''$ - $26^{\circ} 23' 30''$ N and $109^{\circ} 36' 50''$ - $111^{\circ} 29' 30''$ E. Guilin has a rich cultural heritage as well as abundant natural resources. Guilin is developing into an eco-tourism city with the aid of economic growth and pertinent government regulations [8]. The built-up region in Guilin City that is bounded by West Second Ring Road, Liangjiang Avenue, West First Ring Road, Lushan Road, Cuizhu Road, South Third Ring Road, South Second Ring Road, South First Ring Road, and East Second Ring Road was the subject of this study. (as shown in Figure 1). The 102 square kilometer overall area is a part of Guilin City's central urban area. The Xiangshan Scenic Spot, Duxiu Peak City Scenic Spot, Seven Star Scenic Spot, Ludi Scenic Spot, Lijiang River, and other well-known tourist destinations are all located within the research region.

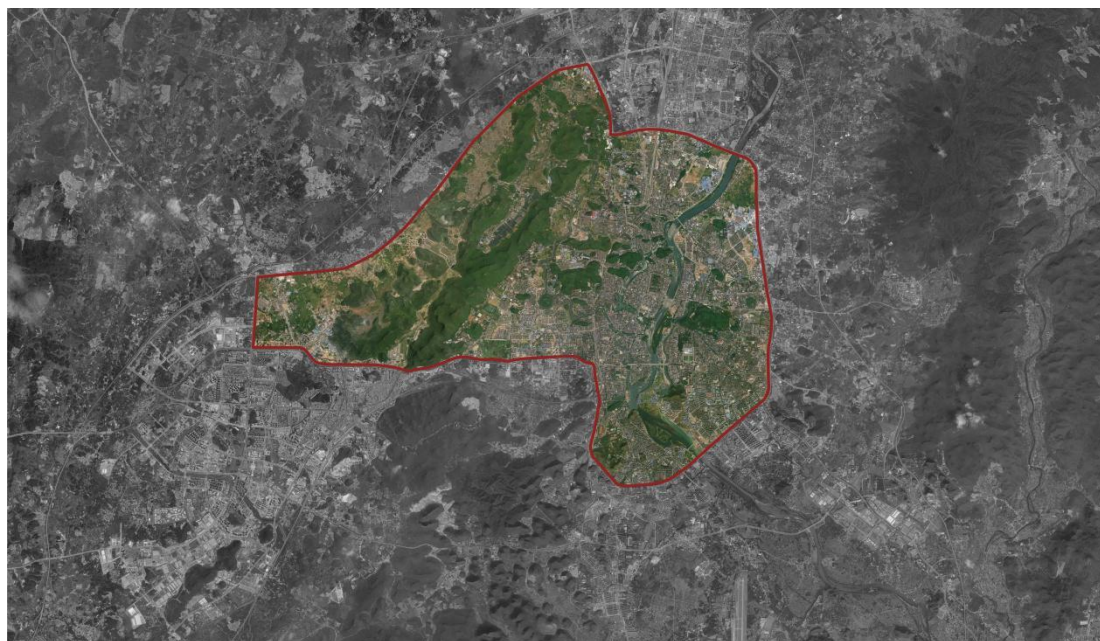


Figure 1. Study area diagram

3. Data Sources and Research Methods

3.1. Data Sources

The analysis of landscape structure and spatial pattern needs to collect and process landscape data first. Remote sensing (RS) and geographic information system (GIS) are commonly used information collection and information processing software. The remote sensing data of this study are from the USGS (<https://earthexplorer.usgs.gov/>) data website. The spatial resolution of the data in 2000, 2014 and 2021 is 30 m, and the cloud content is less than 5 %. The remote sensing data of Guilin in 2000 belong to Landsat 7 ETM + C2 L1 image, and the remote sensing data in 2014 and 2021 belong to Landsat 8 OLI / TIRS C2 L1 image (Table 1).

Table 1. Remote sensing data information

Time (year / month / day)	Image Source	Cloudiness	Spatial Resolution (m)
October 30, 2000	Landsat 7 ETM+ C2 L1	≤5%	30
September 10, 2014	Landsat 8 OLI/TIRS C2 L1	≤5%	30
December 23, 2021	Landsat 8 OLI/TIRS C2 L1	≤5%	30

3.2. Research Methods

This study primarily processes remote sensing data using ENVI5.3 and ArcGIS10.4 software, computes the landscape index using Fragstats4.2, and then integrates the analytic findings [9]. The mechanisms underlying the changes are explored in light of the variations in the Guilin landscape index between 2000 and 2021.

The original remote sensing data is first processed and corrected in this study. Envi5.3 software is used to perform atmospheric correction and radiometric calibration on remote sensing images in order to adjust for sensor and atmospheric imperfections. The maximum likelihood approach in training classification (supervised classification) is used to identify remote sensing images after cutting out the research area. The remote sensing data is converted to GeoTiff format in ArcGIS10.4 and Fragstats4.2 calculates the landscape pattern index. The land classification data in 2000, 2014, and 2021 had kappa coefficients of 0.9460 (OA = 96.33%), 0.9334 (OA = 96.54%), and 0.9023 (OA = 94.30%), respectively. These values met the classification accuracy criteria. Forest land, cultivated land, building land, water area, and unused land are the specific land use kinds that are categorized (Table 2). The term "construction land" refers to cities, towns, villages, and all other types of artificial construction. "Water area" refers to both natural and artificial waters. Forest land encompasses all types of green land, including mountain forest land.

Table 2. Land use classification details

Type	Contains Types
Woodland	Forest land, all kinds of green land
Cultivated Land	Farmland
Construction Land	Cities, towns, villages, artificial constructions
Water Area	Rivers, lakes, paddy fields
Unutilized Land	Urban bare land, forest bare land, undeveloped land

4. Selection of Landscape Index

Landscape index, which is frequently employed in the analysis of landscape pattern, can be used to reflect the structural composition and spatial layout of a certain landscape. More than 400 indices are already available that deal with landscape pattern. Even if the same landscape is examined using several combinations of landscape indices, the final findings will reveal minute variations. According to the suggestion made by Li Xiuzhen et al., when studying and comparing landscape pattern indicators, one should logically choose those that have practical importance and value for the context [10]. In contrast to abusing GIS and remote sensing data to perform endless index and spatial analyses, Harbin Li et al. suggested that we should carefully consider the goal of landscape pattern analysis and seek the optimum solution[11]. This essay focuses on the dynamic shifts in Guilin's landscape from 2000 to 2021. Hu Yujie et al. used the patch level index, landscape level index, and patch type level index to evaluate the dynamics of the landscape pattern in the Nanchong urban region. In order to analyze the dynamic research of six different land use types in Shanghai between 2010 and 2018[12], Yuan et al. chose landscape pattern indexes like total area of patch type, number of patches, and patch density based on the dynamic analysis of landscape pattern in Nanchong City using remote sensing and GIS [13]. It was ultimately decided to use landscape indexes from the two directions of patch type level and landscape level for analysis after consulting the study findings of the two. Six indices at the level of patch type were chosen: Class Area (CA), Percent of Landscape (PLAND), Number of

Patches (NP), Patch Density (PD), Largest Patch Index (LPI) and Landscape Shape Index (LSI) (Table 3). At the landscape level, the following variables were chosen: Patch Density (PD), Number of Patches (NP), Splitting Index (SPLIT), Contagion Index (CONTAG), Shannon's Diversity Index (SHDI) and Shannon's Evenness Index (SHEI) (Table 4).

Table 3. Patch type level index

Landscape Index	Abbreviation	Unit	Implication
Class Area	CA	ha	Total area of a landscape type[14]
Percent of Landscape	PLAND	%	The percentage of the total area of a patch type to the total area of the whole area[15]
Number of Patches	NP	unit	The value is positively correlated with landscape fragmentation[13]
Patch Density	PD	unit /100ha	Patch density was positively correlated with spatial heterogeneity of fragmentation degree[16]
Largest Patch Index	LPI	%	Reflect the concentration of patches and determine the dominant type of landscape[17]
Landscape Shape Index	LSI	-	It is usually used to measure the complexity of landscape patches ; the smaller the LSI value, the more regular the plaque shape[17]

Table 4. Index of landscape

Landscape Index	Abbreviation	Unit	Implication
Patch Density	PD	unit/100ha	Patch density was positively correlated with spatial heterogeneity of fragmentation degree[16]
Number of Patches	NP	unit	The value is positively correlated with landscape fragmentation[13]
Splitting Index	SPLI	%	The value is proportional to the degree of human impact on the ecosystem[13]
Contagion Index	CONTAG	%	The value is proportional to the landscape connectivity[18]
Shannon's Diversity Index	SHDI	-	The higher the index, the more abundant the land use types in the study area[19]
Shannon's Evenness Index	SHEI	-	The index is close to 1, indicating that the landscape patch type is evenly distributed and the diversity is large[19]

5. Analysis of Effect

5.1. Landscape Level Index Analysis

(1) According to the Fragstats calculation results, the patch density (PD) and number of patches (NP) in the research region both showed a declining tendency from 2000 to 2014, from 1527 to 1363. The amount of landscape fragmentation is reflected in patch density (PD) and number of patches (NP). The degree of landscape patch fragmentation increases with the size of the two indices' values. From 2000 to 2014, there was a reduction in the research area's total landscape fragmentation. The land use type map (Fig. 2) shows that in 2000, there were a lot of waters strewn along the research area's perimeter. Landscape fragmentation was lessened in 2014 as a result of the scattered waterways being converted into cultivated or building land, establishing an overall patch. Landscape fragmentation rose from 2014 to 2021, surpassing in numbers the number of patches (NP) and patch density (PD) in 2000. The primary cause is the replacement of the built-up area's building land and forest land. The amount of green space within building sites has gradually expanded due to improvements in urban greening and the creation of block parks, and green spaces of various sizes have appeared within the original construction site area, increasing the degree of overall landscape fragmentation.

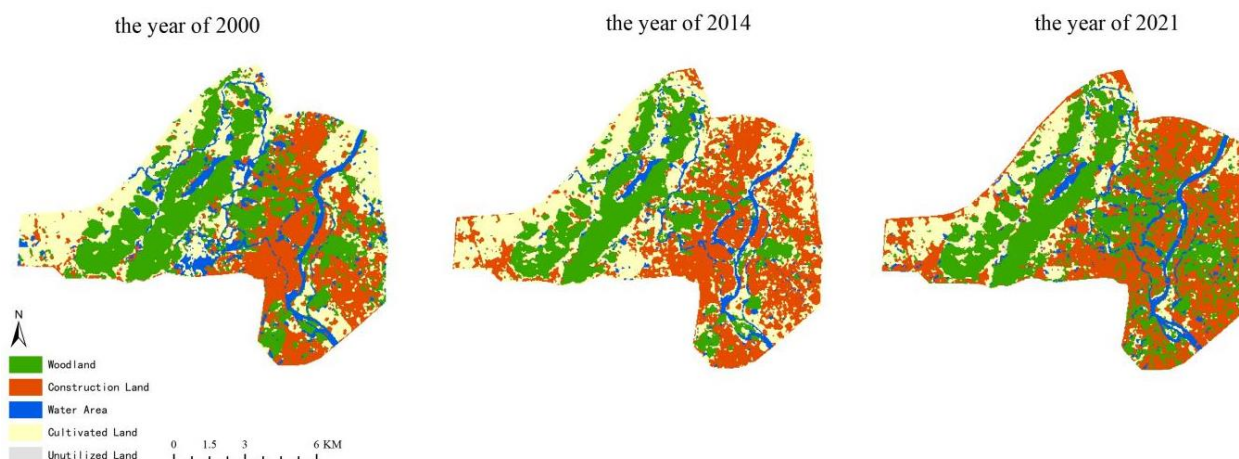


Figure 2. Land use type map of the study area

(2) The contagion index (CONTAG) is a component of the aggregation index, which is primarily used to represent the degree of interconnectedness across various patch kinds. The index's trajectory over the study period—which was inversely correlated with the level of fragmentation—was one of initial increase and then subsequent decline. The contagion index is low because the overall fragmentation of the terrain is considerable, showing that there are numerous dispersed little patches. The splitting index (SPLI) demonstrates the level of human influence on the layout of the landscape. The splitting index exhibits a trend that is first downward, then upward. The value in 2021 is higher than it was in 2000, showing that human activity is ongoing and has an impact on how the entire landscape pattern is laid out.

(3) The dominance and diversity indices are the shannon's diversity index (SHDI) and shannon's evenness index (SHEI). The first is mostly used to explain the diversity and complexity of land use types, while the second is primarily used to explain the uniformity of each patch's distribution. The statistics in 2021 are less than those in 2000, and both indicators reflect a trend of first declining and then growing. Although if the number of patches in 2021 is the highest, their overall complexity and richness as well as their uniformity of distribution are lower than the second-highest number of patches in 2000 when the examination of number of patches (NP) and patch density (PD) is combined. There was no overtly dominant landscape type in 2000, and each patch type was distributed more evenly, according to the shannon's evenness index (SHEI), which was closest to 1. The shannon's diversity index (SHDI), which was highest during this time period, also suggested that the landscape types might be dispersed more equitably. The two indices showed little variation during the study period, demonstrating that the complexity and richness of the overall landscape did not vary significantly and that the different types of landscapes were in a fairly balanced state.

Table 5. Landscape Level Index Results

LID	NP (unit)	PD (unit/100ha)	CONTAG (%)	SPLIT (%)	SHDI	SHEI
the year of 2000	1527	7.7318	53.5891	10.2942	1.3754	0.7676
the year of 2014	1363	6.9014	54.6554	9.5764	1.3486	0.7527
the year of 2021	1785	9.0382	53.3074	10.7524	1.3527	0.755

5.2. Patch Type Level Index Analysis

(1) The amount of building land increased year after year during the study period, demonstrating the existence of human activity and the city's ongoing outward growth and expansion. In 2000 and 2021, the woodland region was dominant. In 2014, the percentage of forest landscape area fell from 34.10% to 25.39% as a result of the expansion of development land. During this time, the city grew and the construction industry grew in order to accommodate the residents' expanding everyday requirements. The percentage of forested landscape area climbed to 36.78% in 2021. In 2021, it will be possible to see from the land use map that some building land will be turned into forest land, as

evidenced by the growth of the number of green areas on both sides of urban highways and the amount of community greening. A portion of the forest and water areas were turned into agricultural land, and then the area of cultivated land increased and subsequently declined. Due to urbanization and other factors, there was a significant drop in the agricultural area on the perimeter of the city that was later developed into construction land. Several of the waters in the study region were once paddy fields, and as they turned into dry land, following land use changes happened as a result. The water area then increased as a result of the development of Guilin's waterscape setting. Given the size and distribution of the various land types, it is clear that the interaction between them in Guilin is complicated by the demands of daily living and zoning regulations.

(2) Number of patches (NP), patch density (PD), and largest patch index (LPI) can show how different plaque kinds are fragmented. The numerical value indicates that the degree of fragmentation of water area, cultivated land, and construction land varies slightly, with the cultivated land type's degree of fragmentation being the most severe of the three types of land use types. Forest land was initially more fragmented, then less fragmented. The little area of green land gradually increased as residential areas and blocks became more vegetated, and the degree of fragmentation peaked in 2021.

(3) The value of building land is rising, which suggests that the edge irregularity of construction land patches is rising, as shown by the landscape shape index (LSI). Apart for the low value of undeveloped land, other categories of land had comparable values in 2000. The complexity and instability of patch edge shape, however, decreased in the 2014 data for forest land, while the increase in LSI data for cultivated land and construction land shows that the shape of landscape types is becoming increasingly complicated and unstable. Even though the water area's edge shape has deteriorated, the magnitude hasn't changed significantly. The LSI value of forest land increased in the 2021 data, surpassing the value in 2000 and about matching the value of building land; nevertheless, the value of LSI also exhibits a negative trend as a result of the shrinking amount of cultivated land. The growth in area and the fragmentation of the terrain also causes an increase in the amount of undeveloped land.

Table 6. Results of plaque type level index in 2000

	Woodland	Cultivated Land	Construction Land	Water Area	Unutilized Land
CA	3501.45	3065.04	2662.02	1033.11	7.02
PLAND	34.10	29.85	25.92	10.06	0.07
NP	449	461	291	312	10
PD	2.2735	2.3342	1.4734	1.5798	0.0506
LPI	8.6142	3.971	6.852	0.6872	0.0123
LSI	20.9215	23.4541	19.7297	22.6186	3.9444

Table 7. Results of plaque type level index in 2014

	Woodland	Cultivated Land	Construction Land	Water Area	Unutilized Land
CA	2607.3	3624.48	3364.02	671.04	3.24
PLAND	25.39	35.29	32.76	6.53	0.03
NP	230	494	260	371	4
PD	1.1646	2.5013	1.3165	1.8785	0.0203
LPI	9.2937	5.5509	8.8329	0.5291	0.0105
LSI	14.2845	29.3035	21.9819	21.711	2.5

Table 8. Results of plaque type level index in 2021

	Woodland	Cultivated Land	Construction Land	Water Area	Unutilized Land
CA	3774.87	2053.89	3636.9	759.78	37.62
PLAND	36.78	20.01	35.44	7.40	0.37
NP	609	472	304	332	64
PD	3.0836	2.3899	1.5393	1.681	0.3241
LPI	8.2264	2.2813	3.1849	0.5751	0.031
LSI	27.2854	24.5743	27.2829	22.5109	8.7317

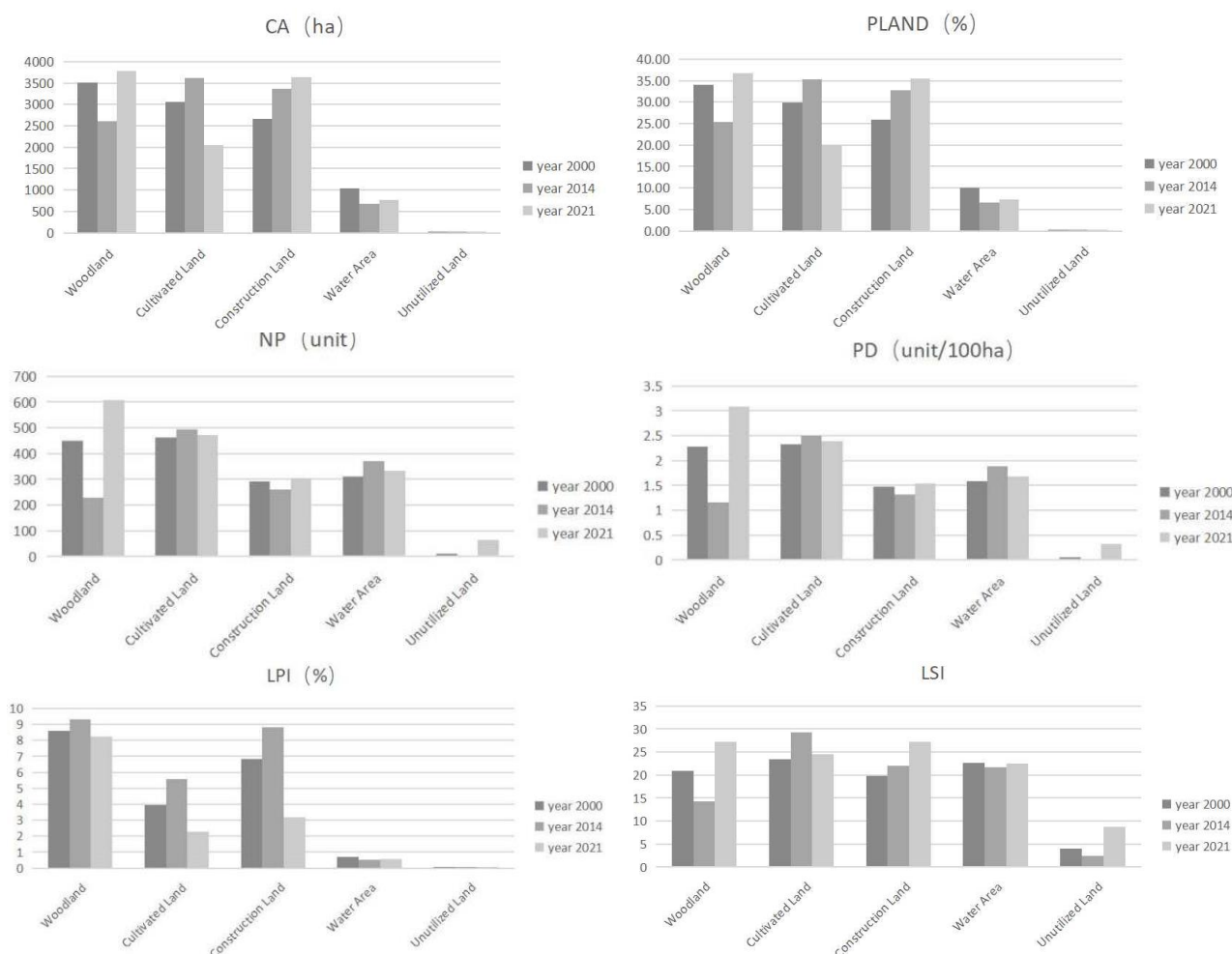


Figure 3. Landscape pattern index on patch type scale

6. Driving Force Analysis

The selection of motivating elements varies slightly across domestic and international experts. Domestic research mostly concentrates on human and natural elements. Overseas research is influenced by a variety of issues, including politics, the economy, science, and technology [20]. This study combines the categories of domestic and international driving forces and examines the forces influencing Guilin's urban growth from the perspectives of policy, population, and economy.

6.1. Policy Factors

Since the People's Republic of China was established, industrial development has taken center stage, and Guilin has developed guidelines for the planning and construction of industrial design highways. The good natural environmental circumstances of Guilin City were not taken into consideration at this point, and the preservation and protection of the natural ecological resources of

the terrain were disregarded. The path of urban development emphasizing landscape planning was not opened until roughly 1960, and the urban planning layout with tourism nature gradually took shape. The ancient urban area, which serves as Guilin City's center urban area, is planned and built along both banks of the Lijiang River, therefore the construction land on both sides of the Lijiang River accounts for more, as can be seen from the land usage map. The water infrastructure that was first landfilled or occupied due to development in Guilin was reused or connected after the picturesque area's creation in 1998. The land use map makes it very evident that there was a closer connection between the seas after 2000. Guilin's connections to other scenic locations have been bolstered, the park's area has grown, and the city's construction practices have steadily become more environmentally friendly thanks to the development of the eco-tourism city. As a result, by 2021, the percentage of forest land will be at its highest, at 34.10 percent. It is emphasized in Guilin City's 2009 "Guilin City Master Plan (2010-2020)" that the central urban area should optimize ecological environment protection and coordinate the relationship between the city and the historical and cultural heritage and landscape by improving the infrastructure and landscape greening of each scenic spot, allowing for the sustainability of both nature and the city. Lingui New District, another city core, shares the old city's development pressure, and it has steadily developed into a new political, social, and cultural hub. The expansion of construction land has slowed while the area of forest land and water area has expanded in the old city, where the primary construction goal is to create a full ecological framework and improve the landscape.

6.2. Demographic Factors

From 4.8201 million in 2000 to 4.9459 million in 2021, Guilin's population rose. The progressive expansion of urban development area is therefore an unavoidable trend because a rise in population must necessitate a greater demand for essential amenities like housing, healthcare, education, and entertainment. Urban construction space in the study region grew from 2662.02 hectares in 2000 to 3636.9 hectares. The extent of forest land also shows the effects of population growth. Residents' expectations for the quality of their living environment have gradually risen as a result of the wealth and development of the economy and society. The expansion in parkland has enhanced the quality of life for locals by enhancing their living conditions. Despite a dip in 2014, strong urban planning and construction practices led to a progressive increase in the woodland area. The land use map makes it abundantly evident that there has been a significant improvement in the greening of urban roadways and communities as well as the greening of inhabitants' living spaces.

6.3. Economic Factors

Guilin is a typical tourist destination, and the tourism sector accounts for the majority of local revenue. Guilin continually enhances its tourism infrastructure in an effort to draw in more visitors. Each beautiful spot's construction has been gradually enhanced as a result of the "Guilin Tourism Development Master Plan (2001-2020)," and several AAAA scenic locations have been created. The increase of quality is what a high-level scenic area entails, and it has very strict standards for supporting infrastructure and landscape greening. Seeing this as an opportunity, each park's greening construction has been bolstered. In the central urban region, the confluence of the Lijiang River, Taohua River, Ronghu Lake, Shanhu Lake, Guihu Lake, and Mulong Lake minimized the fragmentation of the water landscape. This created a good water ecological environment as well as a good landscape. The surrounding economy grows as the natural beauty area gets better, which leads to an annual increase in the amount of construction land.

From the aforementioned motivating elements, it is clear that the construction strategy of beautiful locations has a significant impact on the urban design of tourist cities, and that the transition between various land types is frequently influenced by a variety of circumstances. The conflict between urban expansion and the protection and preservation of landscape resources is excellently resolved by the planning choices made for Guilin's two city centers.

7. Conclusion and Suggestion

According to the research above, it is clear that safeguarding tourism resources is the primary tenet on which tourism cities are built and developed. Construction land is not an infinite extension in terms of the landscape pattern. The construction of the old city, where the research area is located, takes advantage of the two central planning policies of Guilin City and focuses on enhancing the amenities for leisure and tourism getaways, logically connecting the relationship between scenic spots, and creating an ideal ecological pattern. By 2021, despite the fact that the area of construction land is growing annually, it will still be smaller overall than the extent of forest land. The development of landscape greening in the old city is evident from the land use map, as both the greening area on either side of the road and the landscape area within the community have expanded greatly. Similar to this, as tourist attractions fuel economic growth, construction land has been added to the old city of Guilin year after year. However, as a result of measures to protect and preserve scenic areas, this growth pace has halted. As a tourist city, it is important to consider the relationship between the growth of the city and its tourism resources from a variety of angles. The following recommendations are made in light of the findings of the study and analysis combined with the eco-tourism city's long-term development plan:

(1) According to the most recent "Guilin City Land and Space Master Plan (2021-2035) Draft Publication," Guilin's vision for future development is to develop a world-class tourist city, enhance the central positioning of cultural tourism to encourage the development of the surrounding areas, place an emphasis on the preservation of historical and cultural cities, and develop core areas for both culture and tourism. Based on this, the central urban region of Guilin continued to concentrate on enhancing the construction of tourism resources in its later growth. This region should concentrate on creating a decent tourism environment and ecological environment because it is not subject to the pressures of urban growth brought on by the expansion of construction land. Each picturesque location does an excellent job of regreening the surrounding area, and by using native tree species and emulating the region's natural landscape, they create a distinctively green Guilin landscape. By making the most of the current spatial arrangement and promoting tourism to the center urban area rather than hurriedly introducing real estate and constructing a massive mall, it should be possible to draw tourists by preserving and restoring old buildings and artifacts.

(2) Improve the landscape greening on both sides of the Lijiang River, create a full green space corridor, and raise the ecological carrying capacity on both sides of the Lijiang River in accordance with the "14th Five-Year Plan for Ecological Environment Protection in Guilin (2021-2025)". Consider expanding the riverside park in accordance with the various riverside park purpose divisions. The scenic locations are linked to make a full forest patch through the greening of the green spaces, improving the city's ecological advantages and laying the groundwork for the eventual development of Guilin's eco-tourism city. Guilin has abundant natural landscape resources and natural greening advantages that can be used to create an urban green ring.

(3) Rational use of urban fringe agricultural land to develop rural tourism. As a tourist city based on natural resources, Guilin attracts tourists from all over the country. Rural tourism can also be used as a tourism project of the city. Provide diversified entertainment choices by creating agricultural research tours and rural farmhouses. In addition to attracting tourists from the city and the surrounding areas of the city, agricultural culture can also be used as another business card of Guilin, popularizing the farming culture of northern Guangxi for international and domestic tourists, and protecting and preserving the farming culture of Guilin.

(4) The construction land area is suitably constrained in the ancient urban area where the scenic areas are concentrated, and the optimization method is implemented for the existing construction land. For instance, using vacant land in the city for micro-transformation, creating pocket parks and block-sized green spaces to hasten the city's greening process, creating urban green corridors to link scattered green space, and minimizing forest land fragmentation to improve ecological outcomes are just a few examples.

(5) We should draw on Guilin's past development experience when planning the future construction of Lingui New Area and other areas. We should aim to create a landscape city, plan the layout of the city's urban space, coordinate the location of the area's various land uses, and make thorough preparations for the creation of a new Guilin.

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