

The Relationship between Land Use Structure and Industrial Structure in Liupanshui City: A Three-Life Space Perspective

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Abstract: This paper examines Liupanshui City in Guizhou Province as the study area. Utilizing land use and industrial economic data from 2000 to 2020, and employing methods such as the single land use dynamic degree, correlation analysis, and spatial transfer matrix, it analyzes the evolution characteristics and coupling relationship between land use structure and industrial structure from the perspective of the “Production-Living-Ecological Space” (Three-Life Space). The research indicates that the urban space in Liupanshui City has continued to expand, with the dynamic degree reaching 19.30% during 2015-2020, while agricultural space has gradually decreased, and ecological space has remained generally stable. The industrial structure, characterized by a “secondary-tertiary-primary” pattern, has been continuously optimized, with the proportion of the tertiary industry increasing significantly. Correlation analysis reveals a strong positive correlation between the secondary and tertiary industries and urban land use, whereas a significant negative correlation exists between the primary industry and agricultural land. This reflects that while agricultural intensive efficiency has improved, the development of the secondary and tertiary industries still heavily relies on the expansion of construction land.

1. Introduction

Territorial spatial planning serves as a strategic framework through which a nation or region coordinates various development and construction activities within its jurisdiction to achieve sustainable development goals. It possesses distinct public policy attributes and spatial governance functions[1][2]. As a core instrument of the national spatial governance system, territorial spatial planning exerts a profound influence on the adjustment and upgrading of land use structure and industrial structure by optimizing the spatial pattern of development and conservation[3]. By demarcating the “Three Zones and Three Lines” and implementing differentiated spatial regulation strategies, it not only directly constrains the spatial allocation efficiency of land resources but also indirectly facilitates the transformation and upgrading of regional industrial structures through mechanisms such as industrial land supply policies and ecological protection redline regulations[4][5]. Within this institutional framework, the interaction mechanism between land use structure and industrial structure demonstrates distinct characteristics of policy-driven and spatially constrained

dynamics. Therefore, a systematic examination of the coupling relationship and pathways of influence between the two, from both theoretical and empirical perspectives, has become an important research topic.

For years, the relationship between land use structure and industrial structure has been extensively studied in academic circles both domestically and internationally, yielding a relatively substantial body of research. Existing literature generally indicates that during the process of urbanization, the evolution of the industrial structure serves as a major driver of changes in land use types. For instance, industrialization often leads to the conversion of agricultural land into construction land, a phenomenon that has been widely observed and validated in international studies[6]-[10]. Domestic research has further enriched this discourse from the perspective of regional variations. For example, Lu Chunyang et al. [11], taking Chongqing as a case, demonstrated a significant synchronicity between industrial land expansion and the growth of the secondary industry. Meanwhile, Meng Yuan et al. [12], in their study of Beijing, found that the development of the tertiary industry relies more heavily on the effective supply of public service land. In addition, scholars such as Ou Wenting, Qu Aixue, and Yang Yitian[13]-[19] have emphasized, from a policy intervention standpoint, that the optimization of land use structure plays a positive role in promoting industrial upgrading. They argue that especially during economic transition phases, scientifically sound land use planning can provide essential spatial support for industrial evolution. These studies collectively highlight a significant correlation among land use structure, industrial structure evolution, and regional economic development [20].

However, existing literature predominantly focuses on practical discussions in the developed eastern regions, leaving significant limitations in its applicability to underdeveloped western areas. Moreover, these studies often fail to systematically integrate the institutional framework of territorial spatial planning into their examinations. On the one hand, western regions simultaneously face dual constraints of ecological conservation and economic development, implying that their pathways of land use transformation and industrial evolution may fundamentally differ from those in the eastern regions. On the other hand, under the territorial spatial planning system, there remains a lack of robust empirical evidence regarding how spatial governance policies such as the “Three Zones and Three Lines” modulate the synergistic relationship between land use and industrial structure. This paper selects Liupanshui City as a case study—a typical transitioning city in western China characterized by ecological sensitivity and late-development advantages. The formation of its “secondary-tertiary-primary” industrial structure is constrained by the ecological fragility of the karst landscape yet also benefits from abundant local mineral resources. This unique context challenges the explanatory power of existing theoretical models. Against the backdrop of the territorial spatial planning system, this study leverages Liupanshui as a critical case to delve into the interaction mechanisms between land use structure and industrial structure. It aims to address the research gap concerning underdeveloped western regions and provide policy insights for promoting high-quality regional development.

2. Study Area and Research Methods

2.1 Description of the Study Area

Located at the strategic junction of Yunnan and Guizhou provinces, Liupanshui City is a typical concentrated area of karst landform(Figure 1). The terrain is characterized by undulating mountains, with higher elevations in the northwest and lower in the southeast, significant altitudinal variations, complex geological structures, and a fragile ecological environment. The city covers a total area of 9,937. 92 square kilometers and administratively consists of two districts (Zhongshan District and Shuicheng District), one special zone (Liuzhi Special Zone), and one county-level city (Pan Zhou City), with the municipal government seated in Zhongshan District. Benefiting from a subtropical humid

monsoon climate and relatively high altitude, Liupanshui exhibits a unique climatic profile described as “cool, comfortable, moist, and fresh,” earning it the reputation as “China’s Cool Capital. ” The region is rich in mineral resources. However, long-term resource extraction activities interacting with the vulnerable karst ecosystem have led to a series of ecological and environmental issues such as rocky desertification and soil erosion. These conditions make Liupanshui a representative and critical area for studying human-environment interactions and ecological restoration in karst regions. Therefore, selecting Liupanshui as a case study offers significant demonstrative value for exploring the interrelationship between industrial structure evolution and land use structure.

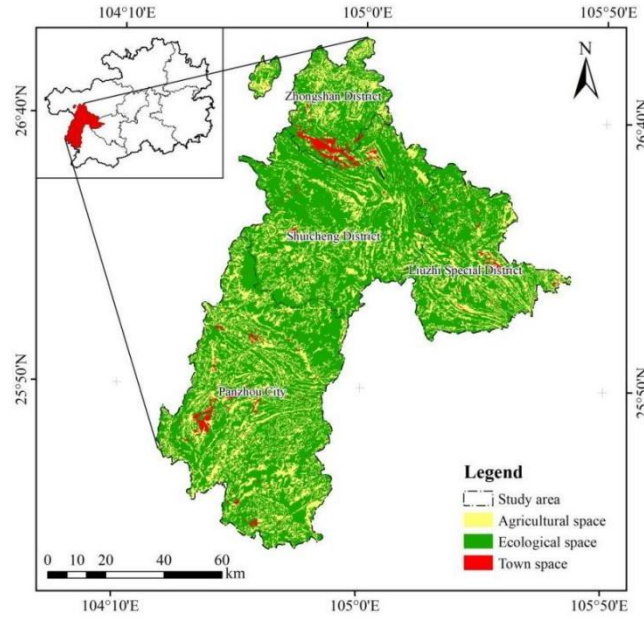


Figure 1 The current situation of land use in Shuipan City in 2020

2.2 Research Methods

This study employs the single land use dynamic attitude model to analyze land use changes in Liupanshui City[21]. On this basis, a systematic investigation combining qualitative and quantitative approaches is further conducted to examine the relationship between land use structure and industrial structure. Using correlation analysis methods widely validated in existing research[21]-[23], the study delves into the degree of interaction and dynamic trends between the two.

2.2.1 Single Land Use Dynamic Degree

The Single Land Use Dynamic Attitude (R_s) can quantitatively characterize the changes in the type and quantity of regional land use over a specific period[24] and effectively reflect the intensity of these changes [25]. The formula is as follows.

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

In the formula: R_s is the dynamic degree of land use; U_a and U_b are the areas of the land use type at the beginning and end of the study period, respectively; T is the study time period[26].

2.2.2 Correlation Analysis Method

Correlation analysis is a multivariate analytical method grounded in statistical theory, whose core principle lies in assessing the degree of linear association and statistical significance between two or

more random variables using quantitative metrics[27].

2.3 Data Sources and Processing Methodology

This study utilized land use data derived from Landsat TM and Landsat ETM images with a spatial resolution of 30 meters for the years 2000, 2005, 2010, 2015, and 2020. The data were obtained from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences (<http://www.resdc.cn>)[28]-[29]. Accuracy verification performed using ENVI software yielded results exceeding 90%, meeting the requirements of this research. Data related to the industrial structure were sourced from the Liupanshui City Statistical Yearbooks of National Economic and Social Development (2000–2020). To investigate the relationship between land use structure and industrial structure in Liupanshui’s territorial space, a classification system linking territorial spatial categories with land use types was established[30], resulting in the construction of a hierarchical classification framework for Liupanshui’s territorial space (Table 1).

Table 1 Integration of the Territorial Spatial Classification System with Land Use Types

Territorial space classification		land use types
Primary Space	Secondary Space	
Town space	Urban living space	Urban land use
	Industrial and mining production space	Industrial and mining land and land for transportation construction
Agricultural space	Agricultural living space	Rural residential land use
	Agricultural production space	Paddy field; dry land
Ecological space	Forestland ecological space	Forest land; shrub land; open woodland; other woodland
	Grassland ecological space	High-coverage grassland; medium-coverage grassland; low-coverage grassland
	Aquatic ecological space	Canal; lake; reservoir pit pond;
	Other ecological spaces	Bare rock texture

3. Results and Analysis

3.1 Spatial-temporal characteristics of land use

3.1.1 Temporal variation characteristics

Between 2000 and 2020, the land use structure of Liupanshui City exhibited significant temporal evolution characteristics. In terms of the proportional share of the three primary spatial types, urban space experienced continuous expansion. Its proportion increased markedly from 0. 45% in 2000 to 1. 94% in 2020. Conversely, agricultural space demonstrated a gradual declining trend, decreasing from 29. 48% to 27. 79%. Ecological space remained largely stable overall, consistently maintaining a share of approximately 70% with relatively minor fluctuations(Table 2). Examining the changing trends more closely, the evolution of various land use types was relatively moderate between 2000 and 2015. However, the period from 2015 to 2020 witnessed a noticeably accelerated expansion of urban space, reflecting an intensification of urbanization and industrialization processes during this time. The persistent contraction of agricultural space indicates the gradual conversion of some agricultural land into construction land(Figure 2). The essentially stable proportion of ecological space highlights the overarching constraints of regional ecological protection policies. In summary, the changes in land use structure in Liupanshui City are characterized by the continual encroachment of urban space upon agricultural space, alongside the general stability of ecological space. This pattern reveals a trajectory of land use transformation shaped by the dual forces of economic development and territorial spatial planning and management.

Table 2 Composition of Different Land Use Spaces in Liupanshui City, Accounting for the Percentage of Total Area (2000–2020)

Year	2000	2005	2010	2015	2020
Town space	0.45	0.49	0.72	0.99	1.94
Agricultural space	29.48	29.40	29.10	29.06	27.79
Ecological space	70.07	70.11	70.18	69.95	70.26

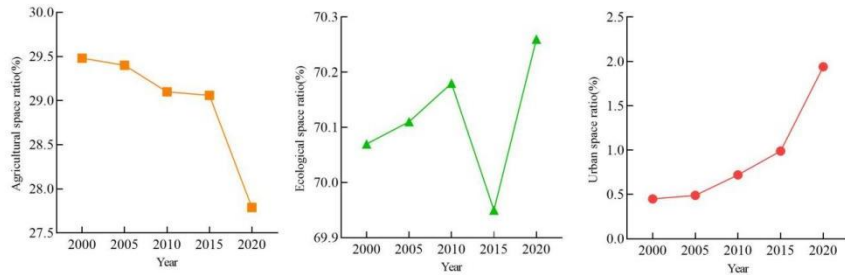


Figure 2 Temporal Changes in the Percentage of Various Land Use Spaces in Liupanshui City (2000–2020)

In terms of the rate of change, the total area of different land use types from various years was incorporated into the single land use dynamic degree formula to calculate the rate of land use change across four development stages (Table 3). A positive value indicates an increase in land area, while a negative value denotes a decrease; the absolute value reflects the magnitude of change, with a larger absolute value indicating more significant change.

Based on the calculated results of the single land use dynamic degree (Table 3), the change rates of different land use types in Liupanshui City from 2000 to 2020 exhibited distinct phased variations and type-specific differences. The dynamic degree of urban space continued to rise, increasing rapidly from 1.55% during 2000–2005 to 19.30% in 2015–2020, indicating an accelerating pace of urban expansion, particularly entering a phase of rapid growth after 2015. The dynamic degree of agricultural space remained negative throughout the period, with a significantly larger decline in the later stage, reaching -0.87% between 2015 and 2020, reflecting an intensified loss of agricultural land. The change in ecological space was relatively modest, with the dynamic degree fluctuating between -0.07% and 0.09%, demonstrating overall stability. However, a slight negative growth occurred during 2010–2015, suggesting some pressure on ecological land during this interval. Overall, the rates of change for all land use types were most pronounced during 2015–2020, indicating that this period was a critical phase of land use transformation in Liupanshui City. The processes of urbanization and industrialization accelerated markedly, while the sustained contraction of agricultural space contrasted sharply with the relative stability of ecological space, highlighting the tension between intense human activity and ecological conservation.

Table 3 Dynamics of Different Land Use Spaces in Liupanshui City (2000–2020)

Land Use Dynamic Degree	2000–2005	2005–2010	2010–2015	2015–2020
Agricultural space	-0.05%	-0.21%	-0.03%	-0.87%
Ecological space	0.01%	0.02%	-0.07%	0.09%
Town space	1.55%	9.42%	7.52%	19.30%

From the perspective of change types, spatial statistics in ArcGIS and Origin were employed for analysis, resulting in land use conversion matrices for Liupanshui City across five distinct periods (Figure 3). These matrices served as the basis for interpreting the transfer conditions among various spatial utilization types.

According to the land use transfer matrix analysis (Figure 3), from 2000 to 2020, the transformation of land use types in Liupanshui City was primarily characterized by significant urban spatial expansion. The increased urban area mainly originated from agricultural space, followed by ecological space. Agricultural production space decreased by a total of 250,600 mu. Part of this reduction involved mutual conversion between ecological and agricultural spaces, which is associated with policies such as returning farmland to forests and returning forests to farmland. The remaining portion was converted to construction space, reflecting a common trend of sustained occupation of cultivated land during rapid urbanization and industrialization.

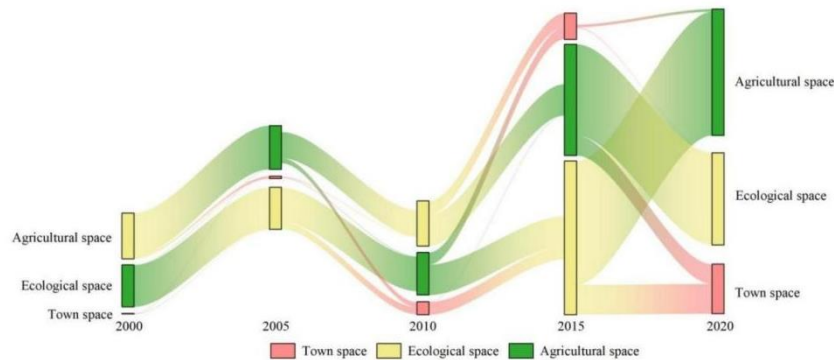


Figure 3 Land Use Transition Matrix of Territorial Space in Liupanshui City for Different Periods (2000-2020)

3.1.2 Spatial Variation Characteristics

As can be seen from Figure 4, in terms of spatial distribution, the changes in different land use spatial types at the three different time points from 2000 to 2010 were not significant. However, during the period from 2010 to 2020, significant changes occurred in the urban living spaces of Zhongshan District and Panzhou City, which progressed markedly faster than those in the surrounding Shuicheng District and Liuzhi Special District. Due to the continuous concentration of population in Zhongshan District and Panzhou City, a substantial amount of agricultural space in the surrounding areas was converted into urban space, indicating that the rate of urban expansion and the transformation of land use spatial types in Zhongshan District and Panzhou City were significantly higher than those in other regions.

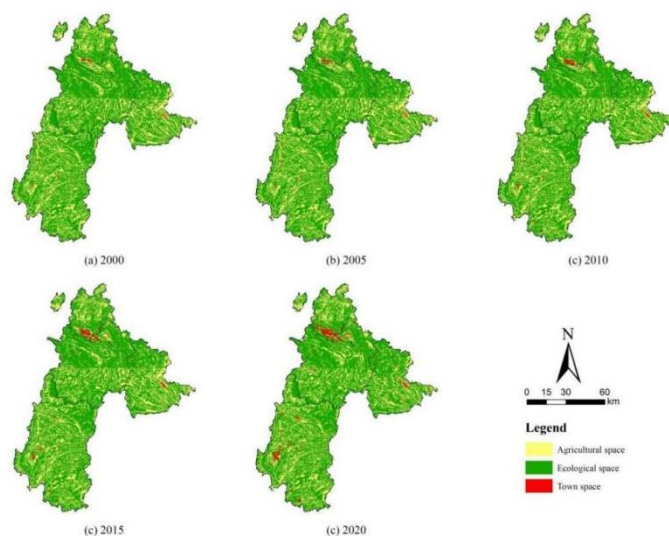


Figure 4 Distribution Map of Territorial Space Types in Liupanshui City (2000-2020)

3.2 Characteristics of Industrial Structural Change

The industrial structure of Liupanshui City maintained a “secondary-primary-tertiary” pattern from 2000 to 2020. However, the proportional composition evolved significantly over this period, shifting from 16.6 : 53.9 : 29.6 in 2000 to 12.7 : 44.8 : 42.5 in 2020. Throughout this time, the share of the secondary industry continued to decline, while that of the tertiary industry consistently rose. In alignment with Guizhou Province’s “Four New Initiatives and Four Modernizations” policy direction, Liupanshui has been steadily optimizing its industrial structure. It is anticipated that the city will eventually transition to a “tertiary-secondary-primary” industrial configuration.

As per capita national income increases, the distribution of labor across the three major sectors follows a predictable trajectory: labor initially moves from the primary industry to the secondary industry, and subsequently from the secondary to the tertiary industry, ultimately resulting in a “tertiary-secondary-primary” industrial structure[31]. Meanwhile, The GDP of Liupanshui City rose from 8.151 billion yuan in 2000 to 133.962 billion yuan in 2020, registering an increase of around 16.44 times(Figure 5).

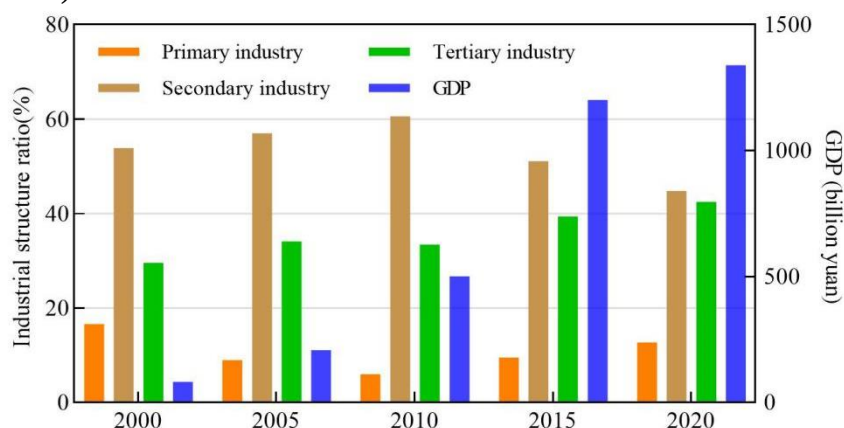


Figure 5 Sectoral Contribution to GDP by Industry and Across Time Periods in Liupanshui City (2000-2020)

3.3 The Relationship between Land Use Structure and Industrial Structure from a "Production-Living-Ecological Space" Perspective: Case Study of Liupanshui City

3.3.1 A Qualitative Analysis of the Mechanism of Interaction between Land Use Structure and Industrial Structure

Land use structure drives the evolution of industrial structure: It directly influences the formation and transformation of industrial structure through the allocation of spatial resources. In Liupanshui City, the continuous expansion of urban space has provided essential spatial support for the secondary and tertiary industries. Between 2000 and 2020, the proportion of urban space increased from 0.45% to 1.94%, and industrial and mining production space also grew significantly. These changes laid a foundation for industrialization and the development of the service sector. Particularly between 2015 and 2020, the dynamic degree of urban space reached 19.30%, indicating rapid expansion of construction land, which effectively supported the clustering and growth of manufacturing, energy industries, and modern services. Although agricultural space experienced an overall reduction, the efficiency of land use was improved through the Grain for Green Program and agricultural modernization, indirectly facilitating the transition of the primary industry toward higher value-added activities. The overall stability of ecological space, meanwhile, provided an environmental foundation

for green industries such as eco-tourism and leisure services. These trends demonstrate that land use structure has significantly promoted the evolution of the industrial structure toward greater efficiency, sustainability, and service-oriented development through supply constraints and spatial guidance.

The industrial structure relies on the land use structure: the optimization and upgrading of the industrial structure, in turn, profoundly influences the transformation of land use patterns. Although Liupanshui City's industrial structure remains of the "secondary-tertiary-primary" type, the proportion of the tertiary sector has increased from 29.6% to 42.5%, while the share of the secondary sector has declined. This reflects a gradual shift in the regional economy from resource dependency toward synergistic development between services and manufacturing. The sustained growth of the secondary sector—particularly energy and manufacturing—has intensified the demand for industrial, mining, and urban land, leading to the continual encroachment on agricultural production spaces. The rapid development of the tertiary sector, especially tourism, finance, and public services, has further driven the expansion of construction land and promoted a transition toward more intensive and functionally composite land use modes. Meanwhile, guided by modern agricultural policies, the primary sector has reduced extensive land use through technological advancements, achieving steady output growth amid a reduction in land allocation. The ongoing advancement of the industrial structure necessitates corresponding spatial and structural adaptations in land resources, thereby driving continuous optimization and adjustment of the land use structure.

3.3.2 Analysis of the Correlation between Land Use Structure and Industrial Structure

Through a correlation analysis of Gross Domestic Product (GDP) and various spatial data of Liupanshui City from 2000 to 2020 using SPSS software, a correlation coefficient matrix was constructed among three types of land use spaces—urban space (CZ), agricultural space (NY), and ecological space (ST)—and the primary industry (DY), secondary industry (DR), tertiary industry (DS), as well as GDP (Figure 6).

The correlation analysis between land use structure and industrial structure indicators in Liupanshui City from 2000 to 2020 reveals a significant systemic relationship between the two. The results indicate a negative correlation between the GDP of the primary industry and the area of agricultural space ($r = -0.90$), suggesting that despite the continuous reduction in agricultural land, the output value of the primary industry continues to grow. This reflects improvements in land use efficiency due to agricultural modernization and technological inputs[32]. A strong positive correlation exists between the GDP of the secondary industry and the area of urban space ($r = 0.81$), indicating that industrial development heavily relies on the expansion of urban land, particularly during the accelerated industrialization phase from 2015 to 2020, when the annual dynamic degree of urban land reached 19.30%, effectively supporting the expansion and agglomeration of the secondary industry.

The GDP of the tertiary industry shows no significant correlation with the area of ecological space but exhibits a strong positive correlation with urban space ($r = 0.90$). This suggests that the development of the tertiary industry does not directly depend on ecological land but relies more on the availability of urban construction land and the improvement of infrastructure, particularly in sectors such as finance, commerce, and tourism.

Overall, there is a clear synergistic evolution between land use structure and industrial structure: the expansion of urban land supports the development of the secondary and tertiary industries, the improved efficiency of agricultural land mitigates the pressure from the reduction of land for the primary industry, and the stability of ecological land provides a foundation for regional sustainable development. This correlation structure profoundly reflects the interaction mechanism between land use and industrial development in Liupanshui City under the multiple objectives of urbanization, industrialization, and ecological conservation.

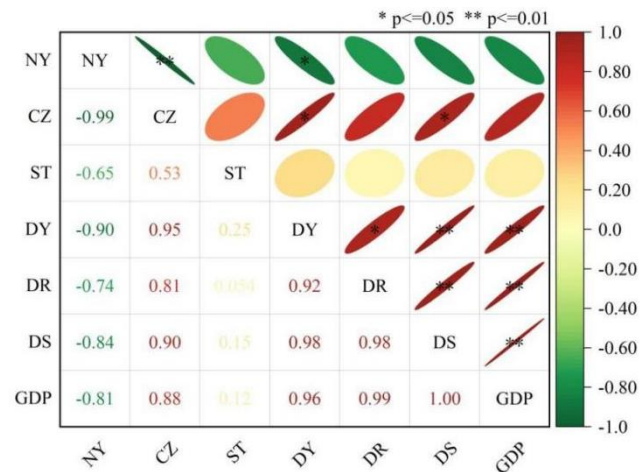


Figure 6 Analysis of the Relationship between the Gross Regional Product and Various Spatial Land Uses in Liupanshui City (2000-2020)

4. Conclusion and Suggestion

4.1 Conclusion

Based on the “Three-Life Space” theoretical framework, this study takes Liupanshui City as a typical case to systematically analyze the evolution characteristics and internal relationship between land use structure and industrial structure from 2000 to 2020. The main conclusions are as follows:

First, significant changes have occurred in the land use structure of Liupanshui City, showing an overall trend of "urban expansion, agricultural shrinkage, and ecological stability with minor adjustments." The proportion of urban space increased from 0.45% to 1.94%, with a dynamic attitude reaching 19.30% during 2015–2020, reflecting rapid urbanization and industrialization. Agricultural space decreased by 1.69%, with an accelerated rate of loss in the later period. Ecological space remained stable at around 70%, indicating the constraining effect of ecological protection. Spatially, the changes showed significant regional differences, with Zhongshan District and Panzhou City experiencing particularly notable urban expansion.

Second, the industrial structure has been continuously optimized. Although it still maintains a “secondary-tertiary-primary” pattern, the proportion of the tertiary industry increased from 29.6% to 42.5%, while the share of the secondary industry declined. This indicates that Liupanshui is transitioning from a resource-dependent economy to one characterized by synergistic development between services and manufacturing. GDP grew approximately 16.44 times, reflecting rapid economic expansion.

Third, there exists a significant interactive relationship and spatial dependence between land use structure and industrial structure. Correlation analysis shows that the secondary industry is highly positively correlated with urban land use ($r = 0.81$), the tertiary industry strongly depends on construction land ($r = 0.90$), and the primary industry is negatively correlated with agricultural land ($r = -0.90$), suggesting that agricultural modernization has improved land use efficiency. Together, these findings reflect the synergy and trade-offs among “production-living-ecological” spaces under the dual influences of industrial drivers and policy regulation.

4.2 Suggestion

First, it is imperative to enhance spatial regulation and prioritize ecological conservation. This

involves the strict enforcement of territorial space use control to curb the disorderly expansion of urban areas, with a focused effort on protecting agricultural and ecological spaces. It is recommended to employ rigid constraints of ecological protection redlines and compensation mechanisms for farmland preservation to ensure that the functionality of “ecological space” does not deteriorate and the quality of agricultural space is improved.

Second, synergizing industrial upgrading with enhanced land use efficiency must be promoted. The internal structure of the secondary industry should be optimized by advancing the intensive transformation and green transition of traditional industries. Concurrently, there should be an active development of high-value-added service sectors to reduce reliance on the expansion of construction land. Efforts should be encouraged to develop green industries such as eco-tourism and wellness services, thereby facilitating the value realization of “ecological space.”

Third, differentiated spatial governance strategies should be implemented. For key urbanization zones (e. g. , Zhongshan District, Panzhou City), stringent land access policies should be applied, promoting the renewal of existing land stock and functional optimization. For ecologically fragile areas, high-intensity development should be restricted, and pathways for realizing the value of ecological products should be explored. Through the coordinated interaction of "industry-land-ecology" policies, a virtuous cycle of the “three-life space” (production-living-ecological space) and balanced regional development can be achieved.

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