Proceedings of ICEGEE 2026 Symposium: Sustainable Environment and Ecology: Supporting a Sustainable Environment for Birds
DOI: 10.54254/2753-8818/2026.BH32611

Research Progress and Prospects of GIS-Based Studies on Spatio-Temporal Patterns of Landscapes in China

Hanwen Zheng

College of Horticulture and Landscape Architecture, Yangzhou University, Yangzhou, China
1021816708@qq.com

Abstract. Research on the spatio-temporal patterns of landscapes is crucial for understanding the complexity of human-land relationships. With the in-depth application of Geographic Information Systems (GIS) technology, the research paradigm in this field has undergone significant evolution, progressing from static pattern identification to dynamic process simulation and expanding towards multidimensional frontiers. This paper systematically reviews the recent applications of GIS in landscape studies in China. At the level of pattern identification, methods of spatial visualization and quantification have revealed the spatial differentiation rules of cultural landscapes, ecological elements, and urban-rural settlements. At the level of process simulation, dynamic models and multi-source historical data have enabled the mechanistic analysis and process reconstruction of urban expansion, landscape evolution, and historical spatial reconstruction. At the level of frontier expansion, the integration of 3D GIS and interdisciplinary methods has deepened research from two-dimensional planes to three-dimensional spaces and from single analyses to integrated simulations. Despite significant progress, current research still faces challenges in integrating historical data, improving the accuracy of 3D models, and intelligently fusing multi-source data. In the future, deepening the application of 3D technology, promoting AI-driven intelligent analysis, developing interactive simulation platforms, and strengthening interdisciplinary methodological innovation will be key directions for advancing research on landscape spatio-temporal patterns to a deeper level.

Keywords: Landscape Spatio-Temporal Patterns, Geographic Information Systems (GIS), Research Progress

1. Introduction

As a spatial carrier formed by the long-term interaction of natural evolution and human activities, the spatial pattern of landscapes often profoundly reflects the complex nature of the human-earth relationship. Traditional studies mostly rely on qualitative descriptions and case analyses, and have certain limitations in the quantitative expression of patterns, the dynamic simulation of processes, and the in-depth analysis of mechanisms. In recent years, with the rapid development of geographic information system technology and its continuous deep integration with remote sensing, spatial statistics, and geoscience models, the methodology of landscape research is undergoing a

DOI: 10.54254/2753-8818/2026.BH32611

transformation - from static description to dynamic simulation, and from two-dimensional planes to multi-dimensional spaces.

The landscape spatiotemporal pattern research based on GIS is a set of methodological systems that integrate multiple spatiotemporal data to conduct quantitative analysis of landscape elements' spatial distribution, temporal evolution, and their driving mechanisms. It uses spatial analysis, visualization presentation, and simulation methods to reveal the formation mechanism and evolution trajectory of landscape patterns. Its essence is to transform traditional qualitative-descriptive landscape features into measurable spatial parameters, establish a correlation model between patterns and processes, and thereby provide support for the scientific prediction and optimization regulation of landscape dynamic changes. In this context, landscape spatiotemporal pattern research has gradually formed an analytical framework integrating pattern recognition, process simulation, and application expansion. Scholars have made significant progress in multiple directions such as the spatial visualization of cultural landscapes, the distribution patterns of ecological elements and natural landscape patterns, the quantitative depiction of landscape patterns, the dynamic simulation of urban expansion, the reconstruction and restoration of historical spaces, and three-dimensional analysis. However, it should also be noted that current research still has shortcomings in the integration and coordination of multiple data sources, the in-depth advancement of three-dimensional analysis, and the integration of cross-scale simulations. It is necessary to systematically review the existing achievements and further clarify the directions that need to be focused on in the future.

This article proceeds along the framework of "pattern recognition - process simulation - frontier expansion". Firstly, it reviews the breakthroughs achieved by GIS in spatial visualization and quantitative methods in terms of spatial distribution of cultural landscapes, ecological elements and natural landscape patterns, and urban settlement patterns. Then, it focuses on dynamic process prediction based on models and historical space reconstruction using multiple data sources, summarizing the technical role of GIS in process simulation and mechanism analysis. Finally, it explores the application prospects of three-dimensional GIS in landscape analysis and the innovative possibilities brought about by the cross-fusion of GIS with multidisciplinary methods such as artificial intelligence and big data. Through this framework, an attempt is made to systematically present the evolution path of the landscape research paradigm driven by GIS, providing some methodological references for the deepening of human-earth system research.

2. Identification of landscape spatial patterns: from visualization to quantification

2.1. Spatial distribution visualization and pattern recognition

2.1.1. Spatial distribution characteristics of cultural landscapes

The spatial distribution research of elements such as place names, religions and heritage in cultural landscapes has gradually shifted from qualitative description to quantitative analysis, with the aid of GIS technology.Scholars have systematically revealed the spatial agglomeration patterns of cultural landscapes and their interactive relationships with the natural and human environment using methods like kernel density analysis and spatial autocorrelation [1,2].

In terms of the cultural landscape of place names, Xiao Bei discovered that the place names in the area surrounding Dongting Lake exhibit a characteristic of circular multi-core clustering in space, and there are significant differences in the distribution of natural and humanistic place names. Zhao Siwen focused on the Yuan River Basin and, through the analysis of the distribution of place names,

DOI: 10.54254/2753-8818/2026.BH32611

summarized three patterns: multi-core clustering, axial extension, and ethnic zoning. From this, one can observe the cultural gradient that gradually changes along the water system.Hong Yongyi's research on the old urban area of Changsha shows that the high-density areas of place names are distributed along the Xiangjiang River. The gradual disappearance of old place names and the emergence of new naming methods reflect the changes in cultural connotations. Zhang Junying discovered that the distribution of names of famous historical sites and ancient buildings in Hunan Province is mainly influenced by human factors. The center of place names shows a trend of migration towards the southeast, which is in line with the process of regional development. In mountainous and rural areas, Zhou Ya et al. revealed the evolution trajectory of place names in Licheng County, Taihang Mountain, from spreading from river valleys to the mountains and then back, and the use of dialect characters and renaming of events constitute important cultural markers. Lin Lin et al. pointed out that the new place names in Newhai experienced a process of center shift to the east during the historical period. The promotion of urbanization led to the separation of traditional place names and commercial names in space, reflecting the rupture of cultural inheritance.

Research on religious and heritage landscapes shows that they often cluster and form corridor patterns in space. Yang Shiyu found that classical gardens in Fujian are relatively concentrated, and they spread south over time with maritime trade. Wang Yiting studied Luofu Mountain and found that Taoist temples and cliff carvings are often located at higher elevations and follow feng shui patterns, and this forms a structure around a central sacred site. Duan Shuang found that Buddhist temples along the Suzhou section of the Grand Canal are arranged in levels along the canal. Wu Huiyan found that religious buildings in Qingxi Ancient City are often placed along the main street in a symmetric way and near water, and this shows the influence of transport and feng shui.In tourism development, Gao Chunliu found that Bon religion landscapes in Jiuzhaigou show a difference between tourist areas and sacred areas, and Wang Yingao used belief contour lines to show the transmission paths of religious culture in northwestern Yunnan.

In summary, the research on the spatial distribution of cultural landscapes has established an analytical framework ranging from pattern identification to mechanism analysis. It has made certain progress in revealing the constraints of natural conditions, the driving mechanisms of human factors, and the evolution process of cultural layers. Looking to the future, it is necessary to further promote the integration of multiple data sources and the construction of dynamic models to better support related work in cultural landscape protection and spatial decision-making.

2.1.2. Agglomeration patterns of ecological elements and natural landscapes

The research on ecological elements and natural landscape patterns has been continuously deepening under the impetus of the integration of GIS and remote sensing technologies, gradually shifting from static description to dynamic process analysis. Studies on different ecosystems have revealed patterns of agglomeration, fragmentation, and gradient differentiation under the interaction of human activities and natural factors [3,4].

In coastal ecosystem studies, Xia Yangli discovered that in Guangxi, the mangroves have an inverse evolution trend where the area shrinks while the patches increase. A distinct differentiation pattern has emerged from the core area to the peripheral area. Human activities such as reclamation and aquaculture are the main influencing factors. Regarding urban natural spaces, Fu Hui et al. pointed out that the natural vegetation in the central urban area of Haikou exhibits characteristics of edge-aggregated and fragmented mosaic distribution.Its distribution is negatively related to the level of urbanization, and this shows how urban expansion reduces ecological space. Soil erosion is a

DOI: 10.54254/2753-8818/2026.BH32611

typical process involving both natural and human factors. Zhu Dun and his team studied Hubei Province and found that soil erosion has generally improved, but some areas are getting worse. The total area of medium and high erosion has decreased, but the number of severe erosion patches has increased, and this shows both protection efforts and development pressure.

In mountainous areas, Yang Yuliang studied the Lancang River basin in northwestern Yunnan and found a clear vertical pattern in natural landscapes. There are settlements in low areas, and farmland and pasture at higher elevations, and this forms a structure linking elevation, vegetation, and land use. Cellular automata simulation also shows how tourism development affects these spatial patterns.

In the quantitative study of spatial patterns, Huang Zijian combined landscape indices with the geographic detector model to study the terrain constraints on the ecological pattern of rural settlements in Mingshan District, and showed that terrain and hydrological factors work together. Liang Fachao and others used fractal dimension and a transport network evaluation system to study changes in settlement boundaries during urbanization, and found that this process increases the fragmentation of ecological land. They also found that higher road network density can improve ecological connectivity, and this shows the different effects of human activities.

Based on these studies, a research approach has formed that includes spatial identification, quantitative indices, and analysis of driving factors, and it shows spatial differences at multiple scales. It also shows how natural conditions and human activities shape space together, and provides useful support for understanding landscape pattern change.

2.1.3. Distribution patterns and evolution of urban and rural settlements

The development of GIS spatial analysis has pushed the study of urban and rural settlements from qualitative description to quantitative analysis. Methods such as kernel density analysis and landscape indices are used to study settlement patterns, and they show how settlements cluster, vary across space, and change over time under the influence of natural and human factors [5,6].

In the study of traditional villages, Wang Qikun and Zhang Xi used landscape gene mapping and GIS analysis to study Hani settlements, and showed vertical ecological patterns and regional differences. Yin Zhiyi found that villages in Huangpi are highly clustered along major roads. Yang Yuliang and others used elevation and slope analysis to study Nuodeng Village, and showed how terrain affects settlement distribution. Lan Tian and others used the MaxEnt model to study the Wujiang River basin, and showed how settlements respond to environmental conditions. Liu Hui and Zhang Gengtong showed how settlements adapt to terrain through their distribution. Chen Xingran and others used elevation and span models to study how villages adapt to different terrain conditions.

Regarding rural settlement evolution, Wang Chengxia pointed out the trend of settlement scale reorganization in Guanghan City. Huang Zijian verified the transformation of settlements in Mingshan District from multi-core to clustered agglomeration and the constraining effect of gentle slopes. Li Yue et al. found that settlement distribution in Jinjiang City is jointly influenced by the natural substrate and human activities, showing different agglomeration characteristics. Mao Ruotong revealed the gradient pattern of settlements in Inner Mongolia's mountainous areas and the nonlinear driving effects of urbanization.

Long-time-series studies have deepened the understanding of urban-rural integration. Lou Yuchen et al. quantified the interaction between natural and socio-economic factors in the Taihu Lake basin. Xu Xin et al. identified polarization trends and spatial reorganization logic in the evolution of settlements in Jiangxi Province.

DOI: 10.54254/2753-8818/2026.BH32611

2.2. Breakthroughs in pattern quantification methods

2.2.1. Quantitative indicator system for urban spatial form

Quantitative studies of urban spatial form have given rise to a multi-dimensional indicator system that spans form indices and the analysis of expansion patterns [7,8].

Hu Kuyu studied Xi'an and showed that fractal dimension can be used to track changes in urban form, and its changes reflect cycles of expansion and infill. Zhang Zhiqing and his team studied Chongqing and used fractal dimension, compactness, and shape index together, and showed that urban development is shifting from outward expansion to internal improvement. Pan Jinghu used national-level comparison and showed that combining different morphological indicators can distinguish spatial development patterns of cities.

For structural features, compactness and spatial syntax can be used together to better understand urban structure. Wang Yao used compactness and integration analysis and found that Urumqi has a stable single-center structure. Hu Kuyu also studied Xi'an's road network with an axial model and found that the core area stays stable, and high-connectivity areas are often near ring roads, showing the strengths of the traditional road system. Li Xian studied Xiangyang and built a matrix linking integration and connectivity, and this provides a new way to study spatial function.

For directional research, Li Lubing used orientation analysis to study small towns in western Jilin and showed that transport guides expansion direction. Yang Zedong proposed a formula to measure connectivity in belt-shaped roads and used it to study changes in road direction. Yin Biao studied Tianjin and showed the change from a single core to multiple cores. Cai Wenting studied Shanghai over a long period and showed the change from river-based growth to multi-center development. These studies use indicators of scale, structure, order, and direction, and they form a basic framework for quantitative analysis.

2.2.2. Application of landscape pattern indices in rural landscapes

Research on rural landscape patterns has achieved precise quantification of settlement space and land use through landscape metrics [9].

Huang Zijian built a dynamic-structural-mechanism framework in Mingshan District and used kernel density and grid analysis to show how rural settlements changed from dispersed to concentrated, and to show the limiting effect of natural factors such as slope. Wei Zhipeng studied the Lankeshui River area and showed a basic pattern of low slope, near water, and along roads. Liang Fachao's team introduced the idea of spatial structure dimension and used correlation analysis between dimension and transport accessibility to show that better road networks improve settlement connections.

Wang Chengxia studied Guanghan City and used multi-period remote sensing images and point-of-interest data to show the expansion and form changes of settlements. Kernel density analysis also shows the outward growth of the center. She built a spatial suitability system with GIS weighted overlay and used it to evaluate development potential in different areas, and this shows the joint effects of natural conditions and human factors. Zhu Dun and his team mainly studied soil erosion, but they also used kernel density and grid analysis, and this provides useful reference for settlement studies.

DOI: 10.54254/2753-8818/2026.BH32611

2.2.3. Emerging methods like landscape gene mapping

The landscape gene mapping method provides a clear way to study settlement cultural landscapes.

Zhao Siwen built a gene classification system for the Yuanshui River basin, including environment, carrier, etymology, and hierarchy. He used feature maps and zonal maps step by step, and this helps to extract cultural traits and show them in space. Wang Qikun and Zhang Xi studied Han communities and built a landscape gene system across nature, space, and architecture, and used a stability-based method to find shared features and regional differences.

Quantitative analysis of genetic spatial characteristics is also developing. Zhou Haoran built a four-dimensional gene system for rural settlements in Tongnan and combined elevation zoning with spatial analysis to show gene distribution patterns, and used regression models to study how genetic stability relates to different factors. Yin Zhiyi proposed a framework to study spatial relationships in villages and towns in Huangpi, and used space syntax to build a system to evaluate genetic spatial effects. Feng Xiaohuan studied Dong villages in Qiandongnan and combined morphological indices with syntactic parameters to show the link between form and spatial characteristics of genetic units.

3. Spatio-temporal process simulation of landscapes: from description to prediction

3.1. Dynamic process prediction based on models

3.1.1. Urban expansion simulation and its driving mechanisms

The integration of GIS and multi-temporal remote sensing data has promoted the development of urban expansion simulation from morphological description to mechanism analysis [10,11]. Yin Biao and his team drew on land use change data and sector analysis to trace how Tianjin's urban space evolved from a single-core agglomeration to a multi-group structure, a pattern they further validated using morphological indicators. Xu Zhendong's long-term study on Zhengzhou reconstructed the city's gradual shift from an ancient walled settlement to a modern metropolis, pointing to transportation hub placement and ecological policies as key forces behind its spatial reorganization.

For driving forces, Wang Yao built a multi-factor indicator system for Urumqi and showed that economic development is the main driver of urban spatial expansion. Cai Wenting studied Shanghai over the past century and showed how natural conditions and major events work together, and also gave a quantitative view of how different policy stages shaped the city.

For predictive models, Mu Fengyun's team used mathematical fitting to show the link between urban expansion and economic growth, and identified future development hotspots. Pan Jinghu built a model that combines economy, terrain, and policy at the national scale, and predicted development trends in different regions. These studies use multi-period comparison, combined indicators, and model optimization, and they provide references for spatial planning.

Studies on cities in special terrains have revealed some unique expansion patterns. Ou Yueqin's investigation of Lanzhou shows that under the constraints of terrain conditions, the city exhibits a band-like expansion feature, and the road network structure also undergoes significant changes. The team of Cui Minmin's research in Xinzheng City observed a coexistence of band-like filling and multi-core development patterns, and noted that the cultural heritage areas have undergone functional changes, which reflects the adaptation mechanism of urban space under special terrain conditions.

DOI: 10.54254/2753-8818/2026.BH32611

3.1.2. Landscape evolution simulation and application

Research on the mechanisms of landscape evolution focuses on quantitative analysis of natural and human factors. Huang Zijian proposed a triple coupling model and used methods such as geographic detectors to show the role of slope and the effects of policy. Wei Zhipeng found that natural factors are the main drivers of landscape change, and also showed how policy affects land use through social and economic factors. Liang Fachao's team used fractal theory to study the effects of transport and industrial development. Zhu Dun's team compared landscape indices and showed the effects of ecological projects and development activities. Zong Lianggang and others used regression analysis to identify the roles of population, urbanization, and industrial structure, and also used GIS to show their spatial effects.

These studies show a clear research path, from pattern study to factor analysis and then to mechanism study. They also help us better understand how landscapes change and provide a base for landscape management.

3.2. Historical spatial reconstruction based on multi-source data

3.2.1. Digital reconstruction of ancient landscapes

The integration of GIS and multi-source historical data has facilitated the digital reconstruction of ancient cities and landscapes [12]. Zhao Chong's team studied the ancient city of Wenzhou and used local chronicles, old maps, and other materials to build a spatiotemporal database covering 800 years. They divided urban development into four stages, and showed how spatial layers formed over time. The study also shows that the road system changed from a mix of water and land to mainly land routes, and public buildings became more dispersed.Zhang Xiaoyu proposed the idea of a spatial gene map and built a multi-dimensional coding system for villages in the Jinshan Mountain area. He used density analysis and morphometric methods to show how natural and human factors shape village form. Wang Changsong's team studied the Western Hills of Beijing and used spatial analysis of many cultural features to track the shift of the cultural center, and showed elevation patterns of different types of heritage.Xu Zhendong studied Zhengzhou using multi-period map comparison and showed the change from an ancient walled city to a modern city. This shows the roles of natural conditions, transport routes, and policy and economic factors over time. Yao Gangzhao studied Handan and used a spatiotemporal database and quantitative indicators to show the change from a dual-core structure to a modern industrial pattern.

3.2.2. GIS integration and spatio-temporal backtracking of historical maps

The digitization and GIS integration of historical maps provide a technical foundation for spatio-temporal backtracking [13]. Scholars often combine historical maps, local chronicles, remote sensing images, and other data sources through spatial registration, and build databases that cover different time periods. Yang Shiyu, for example, built a database for classical gardens in Fujian, and it includes both spatial location and attribute information. Zhou Haoran also used multiple data sources in his study of settlements in Tongnan, and showed how different cultural layers have formed over time in the landscape.

Comparative analysis of multi-period maps has also made progress. Hong Yongyi studied street names in Changsha and used map overlays from the Ming and Qing dynasties to show how name distribution changed over time, and this shows the influence of transport routes and commercial

DOI: 10.54254/2753-8818/2026.BH32611

activity. Li Xiaomeng used data from seven periods to study the ancient city of Jinan, and used spatial analysis to show how natural and human factors shaped the city form.

In the study of toponymic cultural landscapes, Zhang Junying studied changes in settlement place-names over time and used them to show regional cultural features. For spiritual cultural space, Cheng Yue studied Central Park in New York and combined historical drawings with spatial analysis to show how different groups shaped the park. Wu Guoyu and his team used GIS and space syntax to study the spatial effects of cultural factors in traditional settlements. Li Fan's group used historical GIS to study the ancestral hall landscape in Foshan and showed how changes in social structure left clear marks.

These studies show that using multiple data sources to reconstruct historical space can make the process of landscape evolution clearer and can help explain how it works. This method also provides a base for understanding historical development and for protecting cultural heritage.

4. Frontier expansion and integration: from two to multiple dimensions

4.1. Expansion of 3D GIS in landscape analysis

The application of 3D GIS technology expands landscape research from two-dimensional planes to three-dimensional space, demonstrating unique advantages in the analysis of the built environment and natural terrain [14].

On the vertical evolution of architectural landscapes, Shi Huasheng and his colleagues found that Hefei's three-dimensional growth shows a clear polarization, with high-density development in the core area and low-rise, dispersed development in the periphery. Zhang Peifeng and others used multi-period building height data and spatial autocorrelation analysis to show that building types in Shenyang's Tiexi District have gradually changed, and high-rises are now more clustered around transportation hubs, showing the influence of policy on spatial restructuring. Zhang Zhiqing's team, working in Chongqing's main urban area, showed that combining three-dimensional indicators with terrain analysis can measure how mountain cities develop intensively, and can also show how ridge–valley topography limits building placement.

For the simulation of natural terrain processes, 3D GIS provides a way to study spatial adaptation in complex environments. Research on villages in the Jinshan Mountain area, based on elevation gradients and slope thresholds, showed that settlements prefer sunny and gently sloping sites, and this is related to both farming needs and disaster avoidance. Spatial syntax analysis also showed that a stepped layout can improve traffic efficiency on steep slopes. Yao Gangzhao's study of the Handan River basin used digital elevation models and hydrological analysis to show how the three-dimensional nested structure of mountain settlements helps with flood control.

Three-dimensional GIS has clear strengths in showing vertical landscape structure, modeling terrain limits, and analyzing spatial adaptation. But its wider use still faces challenges, including limited historical data, complex model integration, and high computing demands.

4.2. Cross-integration of multidisciplinary methods

Research on landscape spatio-temporal patterns shows a trend of deep cross-integration with multidisciplinary methods. The combination of GIS with technologies such as AI, big data, and Virtual Reality has significantly enhanced the intelligence level of data processing and the immersiveness of spatial simulation [15].In the visualization and simulation of surface processes, Ji Fengquan and others used digital elevation models and hydrological analysis to reconstruct the

DOI: 10.54254/2753-8818/2026.BH32611

evolution of the water system in Hongcun Village, Huizhou, and evaluated the performance of the man-made water channels. Zhu Dun and others combined erosion transfer matrices with landscape indices to study how human activities affect soil erosion patterns. Yang Yuliang showed that transport hubs and terrain factors work together in spatial restructuring.

These cases show the value of combining different methods. Artificial intelligence helps improve pattern recognition for large spatial datasets, and big data analysis shows the links between different driving factors. Virtual reality and augmented reality also provide new ways to reconstruct historical scenes and evaluate planning schemes. This kind of integration enriches research methods, and it also supports a shift from static description to dynamic simulation, and from pattern study to mechanism study, and helps us better understand how human and natural systems change together.

5. Conclusion and prospects

During the stage of landscape spatial pattern identification, GIS technology helped push research on cultural landscapes, ecological elements, and the distribution of urban and rural settlements in China from qualitative description toward quantitative analysis. Methods such as kernel density analysis and landscape pattern indices have brought to light spatial differentiation patterns shaped by the interplay between natural substrates and human activities. During the development of landscape spatiotemporal process simulation, research gradually shifted from static description toward more dynamic forms of prediction. Studies focusing on urban expansion, landscape evolution mechanisms, and historical spatial reconstruction have contributed to a more nuanced understanding of how landscapes change over time and the processes driving these transformations.

In the subsequent stage of methodological expansion, the incorporation of 3D GIS alongside multidisciplinary perspectives further extended the scope of research. This shift not only moved analysis beyond two-dimensional representations but also encouraged more integrated and comprehensive approaches.

Current research still faces several technical challenges. The acquisition and processing of historical data remain difficult, particularly for historical maps, where inconsistencies in accuracy and spatial alignment reduce the reliability of long-term time series analysis. Three-dimensional analysis techniques also require further refinement; in complex terrain modeling and large-scale computation, limitations persist in data integration and processing efficiency. The integration of multi-source data likewise needs improvement, as effectively combining heterogeneous datasets and identifying their interrelationships remains challenging. In addition, existing models often show limited adaptability to local conditions and unexpected events, which may affect the accuracy of simulation results.

References

[1] Zhou, Y., Yu, L., & Yue, Y. (2022). GIS-based analysis of rural toponymic cultural landscape in the Taihang Mountains: A case study of Licheng County, Shanxi Province. Journal of Arid Land Resources and Environment, 36(8), 68-76. https: ///10.13448/j.cnki.jalre.2022.201

[2] Lin, L., Wang, X., & Zeng, J. (2021). Distribution, evolution and influencing factors of place-name cultural landscape in Xinhui based on GIS. Acta Scientiarum Naturalium Universitatis Sunyatseni, 60(5), 72-85. https: ///10.13471/j.cnki.acta.snus.2020d017

[3] Fu, H., Fu, G., & Xu, X. (2015). Spatial structure analysis of green space landscape in Haikou City based on RS and GIS. Chinese Journal of Tropical Crops, 36(1), 205-210.

[4] Liang, F., Liu, S., & Liu, L. (2017). Spatial characteristics and evolution of rural settlement landscape based on fractal theory: A case study of Xiamen City. Chinese Journal of Applied Ecology, 28(8), 2640-2648. https: ///10.13287/j.1001-9332.201708.037

[5] Wang, Q., & Zhang, X. (2022). A comparative study on landscape spatial differentiation in ethnic areas from the perspective of rural revitalization: A case study of Honghe Hani settlements. Urbanism and Architecture, 19(23), 189-193. https: ///10.19892/j.cnki.csjz.2022.23.39
[6] Lan, T., Sun, X., Yan, J., Deng, B., & Huang, B. (2025). Spatial distribution and local characteristics of traditional villages in the Wujiang River Basin. Journal of Southwest University (Natural Science Edition), 47(8), 216-226. https: ///10.13718/j.cnki.xdzk.2025.08.018
[7] Pan, J., & Han, W. (2013). Spatial form evolution of provincial capitals and above cities in China in recent 20 years. Journal of Natural Resources, 28(3), 470-480.
[8] Yang, Z. (2023). Simulation analysis of evolution characteristics of urban ribbon road landscape spatial pattern. Modern Electronics Technique, 46(15), 113-116. https: ///10.16652/j.issn.1004-373x.2023.15.020
[9] Wang, C. (2024). Research on spatial pattern evolution and optimization strategy of rural settlements in Guanghan City based on GIS. Agriculture and Technology, 44(11), 77-82. https: ///10.19754/j.nyyjs.20240615019
[10] Yin, B., Wang, L., & Song, Y. (2024). Morphological evolution and driving development: A study on Tianjin's urban spatial expansion and influencing factors. *Modern Urban Research, (2), 1-8.
[11] Cui, M., Xie, L., & Wei, F. (2019). Research on urban spatial form evolution based on GIS and historical maps: A case study of the relationship between the ancient city of Zheng-Han and the development of Xinzheng City. *Chinese and Overseas Architecture, (4), 111-115. https: ///10.19940/j.cnki.1008-0422.2019.04.032
[12] Zhao, C., Kong, L., & Gan, G. (2024). Study on the spatial stratification process and characteristics of historical landscape in Wenzhou ancient city. Huazhong Architecture, 42(11), 84-89. https: ///10.13942/j.cnki.hzjz.2024.11.002
[13] Li, F., Zhu, H., & Huang, W. (2009). The evolution of clan cultural landscape and the differentiation of socio-cultural space in Foshan from the Ming Dynasty to the early Republic of China: A perspective from ancestral halls. Scientia Geographica Sinica, 29(6), 929-937.
[14] Shi, H., Li, J., & Bao, Y. (2021). Study on the spatio-temporal evolution of urban vertical spatial growth in Hefei City. Anhui Agricultural Science Bulletin, 27(4), 165-168. https: ///10.16377/j.cnki.issn1007-7731.2021.04.061
[15] Ji, F., Wang, M., & Zhang, X. (2025). Study on the spatial construction characteristics and evolution mechanism of the water system landscape in Hongcun, Huizhou. Small Town Construction, 43(2), 46-55.