Research Paper

Study On Ecological Restoration Of Chongqing's Liangjiang New Area Based On The Evaluation Of Landscape Ecological Security Patterns

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Abstract

Against the background of great challenges to the urban ecological environment, building a reasonable urban ecological infrastructure pattern is an important guarantee to enhance urban ecological security and achieve sustainable development. Based on the landscape ecological security pattern theory, this paper analyzes the hydrological system security pattern, the geological hazard security pattern, the bio-protection security pattern, and the vernacular culture security pattern in Liangjiang New Area of Chongqing Municipality. With the technical support of GIS and RS spatial technology, a integrated landscape safety pattern is constructed, and three ecological safety zones of different safety levels, low, medium and high, are identified. Finally, the ecological restoration space of Liangjiang New Area is identified by overlaying the low-security pattern integrated landscape safety pattern and construction land, and four ecological restoration strategies are proposed: 1. Safeguard ecological space and maintain biodiversity; 2. Ensure water safety and strengthen shoreline control; 3. Optimize green space structure and enhance the recreational experience; 4. Mitigate geological hazards and implement dynamic monitoring. This study hopes to provide a reference for ecological restoration planning and implementation in other regions.

Keywords

Landscape ecological safety patterns, Ecological restoration, Landscape planning, Minimum cumulative resistance model, GIS

1. Introduction

As China's urbanization process continues to accelerate, cities are expanding rapidly. More and more hard surfaces such as buildings, squares, and roads in cities have led to less and less area for ecological infrastructure such as wetlands and green spaces in cities, exacerbating urban ecological problems such as urban flooding, heat island effect, water eutrophication, and atmospheric pollution (Zhang, & Xue, 2017). When the ecological infrastructure of cities is severely damaged, the level of ecosystem services and self-regulation capacity will be significantly reduced, and ecological restoration and ecological construction activities need to be carried out through natural restoration or human intervention.

Landscape ecological safety pattern is based on the theory and method of landscape ecology, based on the relationship between landscape processes and patterns, and the analysis and simulation of landscape processes to discern a landscape pattern with health and safety significance. The approach of landscape ecological safety pattern is to maintain and control ecological processes or other horizontal processes by treating landscape processes of ecological infrastructure (EI) (including regional hydrological cycle, diffusion of hazard processes, spatial movement of species, urban sprawl expansion, etc.) as processes that achieve landscape control and coverage by overcoming spatial resistance(Xiao, & Liu,2017; Yu,1999).

Ecological restoration practices in China have focused on the study of small-scale locally damaged spaces, such as eutrophication management of rivers and lakes, reclamation and ecological restoration of abandoned mine lands, and restoration of salt marsh wetlands (Huang, & Hu,2016). Although the local ecological restoration has achieved good results, the overall ecological function enhancement is still limited due to the lack of systematic consideration of spatial layout (Fang, et al.,2020). By applying the method of landscape ecology, coupling dynamic ecological processes with static landscape structures, identifying areas for ecological restoration and ecological construction, and proposing corresponding ecological restoration strategies, it is important to guarantee the integrity and health of ecosystem functions, maintain regional ecological security, and promote the construction of ecological civilization for sustainable urban development (Peng, et al.,2017; Hodson, & Marvin,2009).

Under the call of "beautiful Chongqing, the capital of landscape", Chongqing Liangjiang New Area has an urgent need to balance urban development and ecological planning. Based on the concept of landscape ecology, this paper identifies different types of landscape security patterns, superimposes each single ecological security pattern to build a integrated landscape safety pattern with different security levels, divides ecological security zones, identifies ecological conflict spaces, and proposes corresponding ecological space protection and restoration strategies. This study is expected to provide a reference for other regional ecological protection and restoration research and practice.

2. Study area and method

2.1. Study area

Located in the west-central part of Chongqing, north of Yangtze River and east of Jialing River, Liangjiang New Area is located at 29°33′54″N~29°54′02″N, 106°26′04″E~106°45′35″E, with a total area of about 1200km^2 (Figure 1), and is the first national inland development and opening new area in China. The area has a mid-subtropical monsoon climate, with an average annual temperature of 18℃ and an average annual precipitation of about 1090mm. The whole area is composed of parallel valleys from the northeast to the southwest of Zhongliang Mountain, Longwangdong Mountain, Tongluo Mountain and Mingyue Mountain, with the terrain sloping gently from the northwest to the southeast, and the natural terrain of the area is nearly 60%. The water system in the area is well developed, with 12 primary tributaries, 12 secondary tributaries and a number of tributaries, 43 large and small reservoirs, and many ponds, with the Yangtze River as the main stem, together forming a huge water network system in the direct control area.

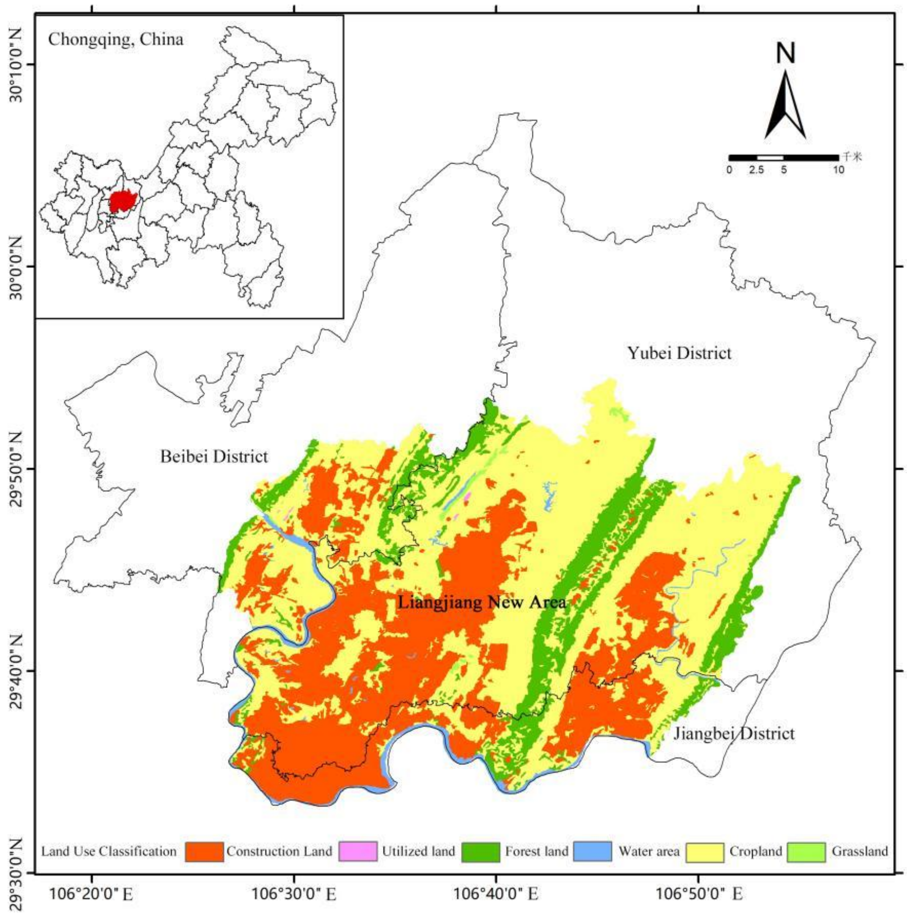

Figure 1. Location of Chongqing Liangjiang New Area. Source: Drawn by author.

2.2. Minimum cumulative resistance model

The minimum cumulative resistance model (MCR) is a mature method for identifying landscape ecological safety patterns, which refers to the resistance surface model formed by the minimum resistance overcome during the migration of species from the source to the target source and can analyze the degree of separation of landscape patches and serve as a basis for landscape pattern optimization. The MCR model is calculated as follows.

$$MCR = f_{min} \sum_{j=n}^{i=m} (D_{ij} \times R_i)$$

where "MCR is the minimum cumulative resistance value, f_{min} is positively correlated with MCR and denotes the spatial distance between the minimum resistance at any point in space and the base plane i of a landscape it passes through, D_{ij} denotes the distance from source j to the base plane i of a landscape it passes through at any point in space; and R_i denotes the resistance of landscape i to the movement of a creature"(Ni, et al., 2020; Mahmoud, & El-Sayed, 2011).

2.3. Construction of ecological infrastructure in Liangjiang New Area

"Urban ecological infrastructure can provide four ecological services: regulating services, supporting services, supply services, and cultural services" (Gill, et al.,2007). These ecological services play an important role in urban development, and the security pattern of these ecological services can be maintained through ecological restoration. Based on the classification of ecosystem services of ecological infrastructure, this paper analyzes the structure of urban and rural non-construction land in Liangjiang New Area and establishes the landscape ecological safety pattern of hydrology, geology, biology and vernacular culture by drawing on the concept of landscape ecology. The landscape pattern security degree is divided into high, medium and low, and the higher the level indicates the higher the landscape security degree and the lower the ecological risk faced.

(1) Hydrological system safety pattern in Liangjiang New Area

The hydrological system safety pattern guarantees the safety of the urban water system ecosystem and is the base point of urban safety. The hydrological system safety pattern of Liangjiang New Area integrates the rain and flood safety pattern and the water source protection safety pattern.

Flooding is part of the inevitable natural process of rivers and a landscape process. Large-scale flooding can cause loss of people's property and lives as well as environmental damage, but flood risks can be effectively avoided by some technical means such as watershed management and the establishment of flood-stagnant wetland patterns. The rainfall safety pattern in this paper is based on water level-based flood inundation extent analysis, using ArcGIS hydrological analysis tool to realize runoff simulation, identify the location and extent of depressional wetlands, etc., calculate the flood surface and terrain elevation difference based on the collected flood levels of different recurrence periods, and identify the flood safety level under different flood risk levels.

Water sources are important elements of ecological processes such as climate regulation and biological survival. By identifying different types of water sources through land use data and using ArcGIS buffer zone analysis to establish a multi-level water source protection security pattern, it can realize the protection of surface and groundwater resources and maintain the continuity and integrity of the regional water system pattern.

The rainfall security pattern and water source protection security pattern were spatially calculated to obtain the hydrological system security pattern of Chongqing Liangjiang New Area (Figure 2).

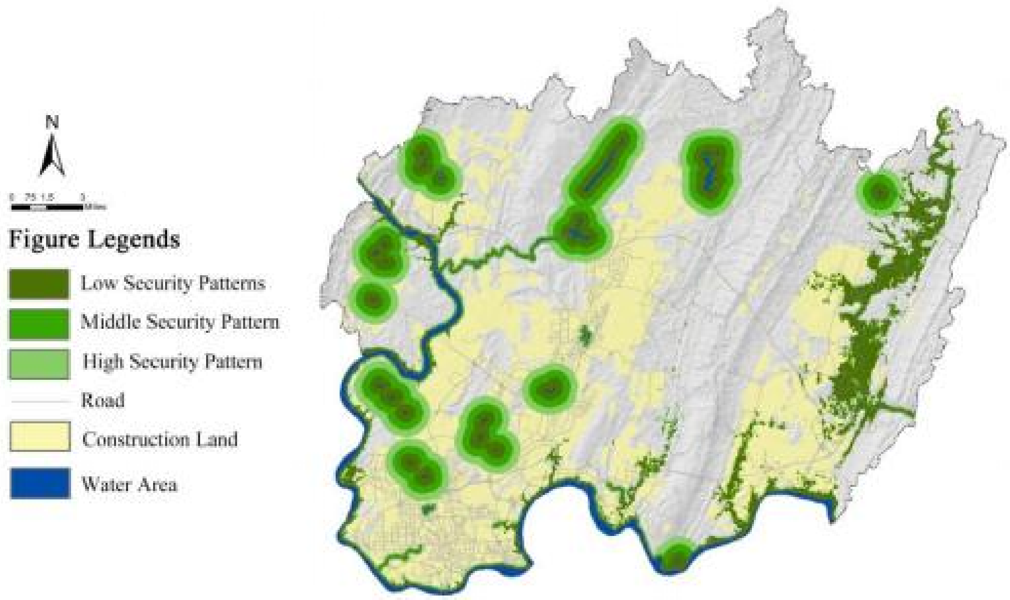

Figure 2. Hydrological system safety pattern in Liangjiang New Area. Source: Drawn by author.

(2) Geological hazard safety pattern in Liangjiang New Area

In-depth analysis of the causes of geological hazards is usually related to natural substrate conditions and artificial activities. Regional precipitation, soil, land use, geology, vegetation cover, slope, elevation and other evaluation indexes were selected for the erosion sensitivity evaluation and landslide sensitivity evaluation analysis (Lv, et al.,2020). The geological hazards in Liangjiang New Area present characteristics such as many points, many types, small scale and large hazards. The main types of geological hazards are landslides, unstable slopes, reservoir banks, dangerous rocks and so on. 196 geological hazard points that are unstable to the present or future are selected for buffer zone analysis. Based on the erosion evaluation, landslide evaluation analysis and buffer analysis of geological hazard points superimposed to constitute the security pattern of geological hazards in Liangjiang New Area (Figure 3).

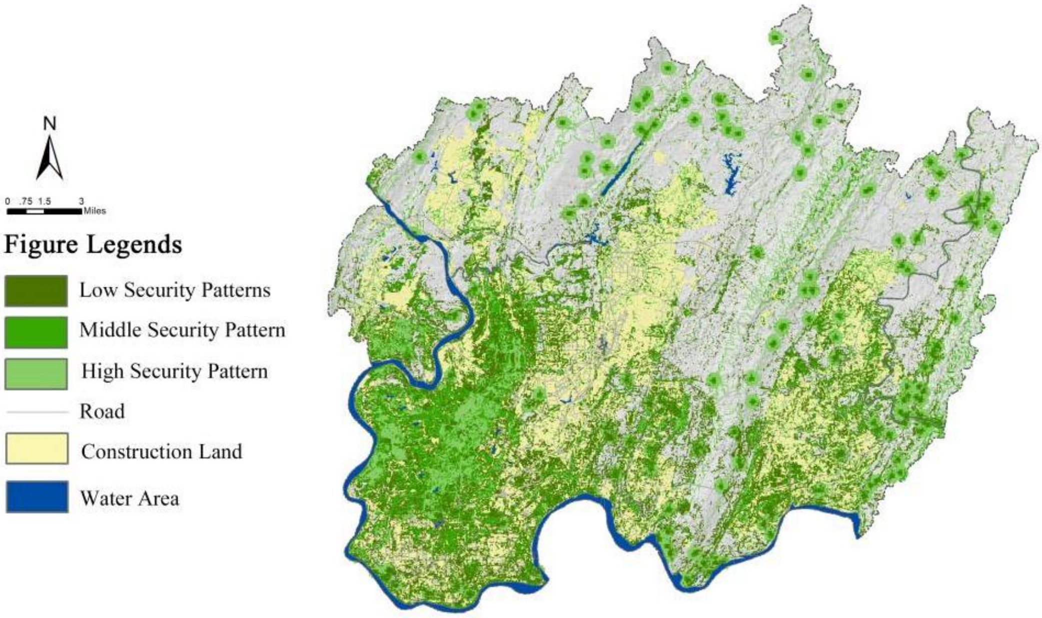

Figure 3. Geological hazard safety pattern in Liangjiang New Area. Source: Drawn by author.

(3) Biological Protection and Security Pattern in Liangjiang New Area

Biological conservation pattern is a horizontal ecological process analysis by constructing a minimum resistance model (MCR) to simulate the minimum resistance that organisms need to overcome in spatial movement. The security pattern of biological processes consists of sources, buffers, corridors and radial paths, and strategic points, which are coupled with patches, substrates, and corridors on landscape security, reflecting proactive and opportunistic strategies, with more emphasis on connectivity. Habitat source sites are the source sites for species dispersal and maintenance, and their connotations include the three most important characteristics: (i) maintaining the integrity of landscape processes; (ii) ensuring the sustainability of ecological services; and (iii) preventing ecological problems caused by ecosystem degradation. In this paper, the nature reserves of Liangjiang New Area, areas of high ecological protection, woodlands with an area larger than 1 km2, Yangtze River, Jialing River and various tributaries were considered as habitat source sites. The spatial resistance of biological movement through different land cover types is assigned, and ArcGIS is used to analyze the cost distance and corridor to obtain the resistance surface of biological movement and the minimum resistance biological migration corridor, forming the biological protection security pattern of Liangjiang New Area (Figure 4).

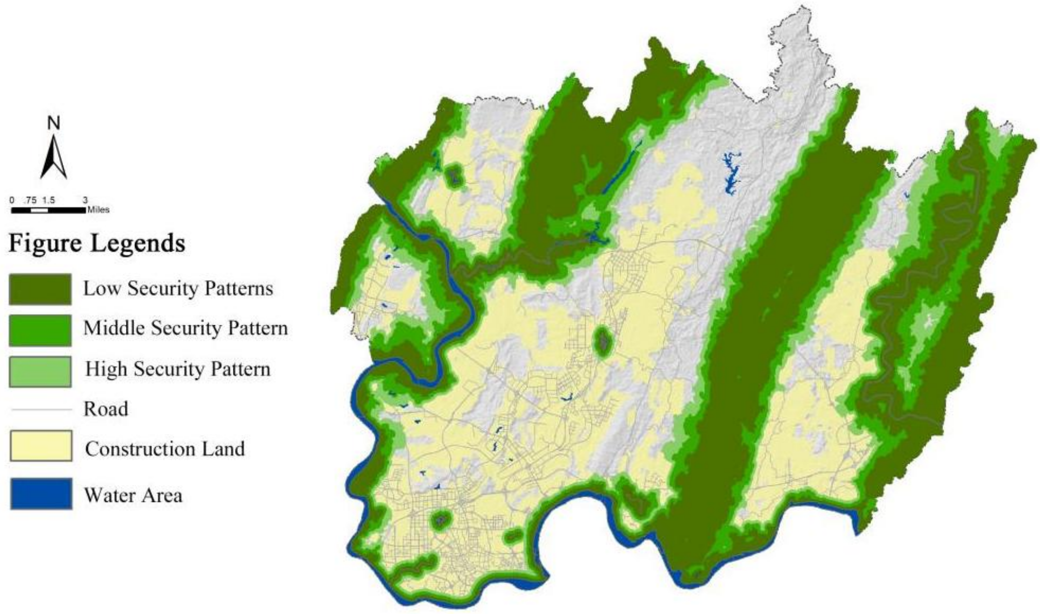

Figure 4. Biological Protection and Security Pattern in Liangjiang New Area. Source: Drawn by author.

(4) Vernacular Culture Security Pattern in Liangjiang New Area

Many studies on ecological networks, green infrastructure, and ecological infrastructure focus more on natural ecological processes and lack consideration of human ecological processes, and the vernacular cultural landscape surrounding or embedded in the city has not been given enough attention (Han, et al.,2019). In fact, vernacular nature is closely integrated with people's production and life and is ecologically a benign disturbance. Interrupting or excessively disturbing this vernacular nature process will cause changes to the relatively stable landscape structure deposited by history. In terms of ecosystem services, vernacular cultural landscapes can provide people with a variety of functions such as cultural diversity, spiritual and religious values, recreation and ecotourism, aesthetic values, knowledge systems, and educational values(Jongman,1995). The ecological infrastructure can be deeply understood as a dual carrier of cultural and natural functions, and the vernacular cultural landscape elements in the region are regarded as the "source" and people's resting activities as the process of horizontal expansion to build the vernacular cultural landscape security pattern. The natural and humanistic landscapes of Zhongliang Mountain, Longwang Cave, Central Park, Jialing River, Yangtze River, Luohan Temple, Taoranju, Renhe Pagoda, and other places in Liangjiang New Area are selected as the sources of the vernacular cultural security pattern. The spatial resistance coefficients are set according to different land use types, and the minimum cumulative resistance surface is established by the MCR model to obtain the vernacular cultural landscape security pattern of Liangjiang New Area (Figure 5).

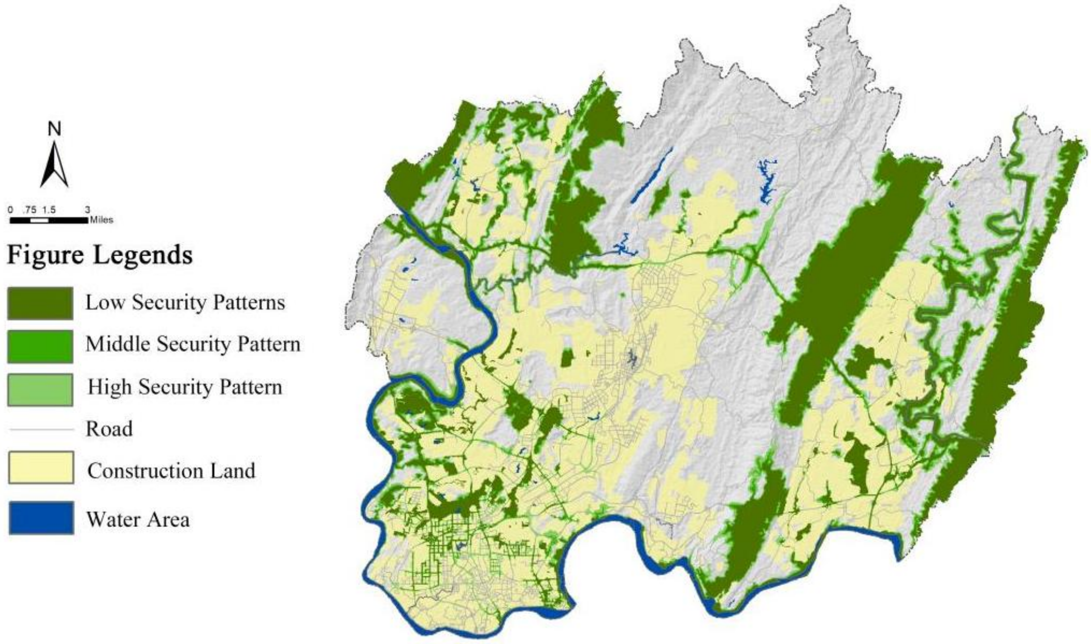

Figure 5. Vernacular Culture Security Pattern in Liangjiang New Area. Source: Drawn by author.

3. Findings

3.1. Ecological safety zoning

The integrated landscape safety pattern was obtained by calculating and overlaying the hydrological system security pattern, biological protection security pattern, geological hazard security pattern and vernacular culture security pattern through ArcGIS (Figure 6). The integrated landscape safety pattern is used as ecological security zoning for ecological control. The ecological security zoning of Liangjiang New Area includes 3 levels of zoning. Low-security pattern 626.5km^2, accounting for 52.2% of the whole area, includes the core areas of major mountain rivers, reservoirs, geological hazard points and vernacular landscape points. This partition is the bottom line to guarantee regional ecological security, with ecological conservation as the main focus and strict control of urban construction activities. Medium-security pattern 190.3km^2, accounting for 15.8% of the whole area, including the buffer area of mountain rivers, and rural landscape area, this partition is to maintain the appropriate scale of the region's complete ecological process, to protect and restore the main, limit the development and construction activities, moderate recreational activities. High-security pattern 157.5km^2, accounting for 13.1% of the whole area, including small mountains, small watercourses, road traffic scattered farmland and green areas, this sub-region is ideal for ecosystem service functions, can be conditioned to moderate agricultural production and urban and rural development according to the specific local conditions (table 1) (Zhao, et al.,2021).

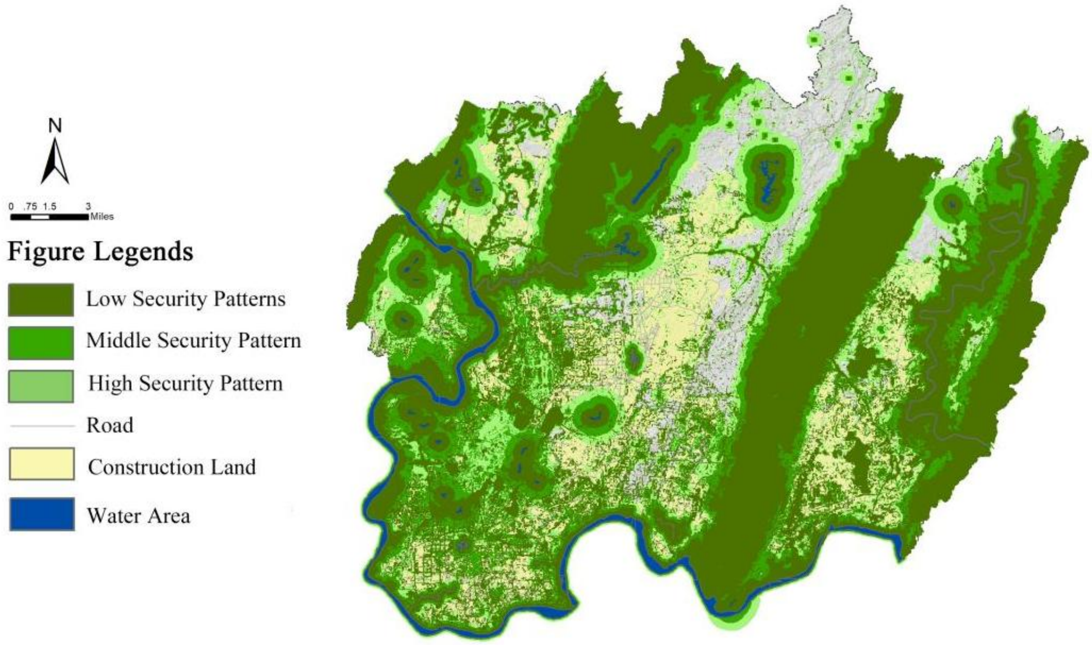

Figure 6. Ecological Safety Zone of Liangjiang New Area. Source: Drawn by author.

Table 1. Ecological safety zoning. Source: Drawn by author.

Level	Area (percentage)	Region	Protection and utilization methods
Low-Security Patterns	626.5km^2 (52.2%)	Zhongliang Mountain, Longwangdong Mountain, Tongluo Mountain, Mingyue Mountain, Longgang Mountain, Phoenix Mountain, Wolong Mountain, Baiyun Mountain, Zhaomu Mountain; along Yangtze River, Jialing River, Panlong Creek, Yulin River, Houhe River, reservoirs, geological hazard sites, rustic landscape sites	Strictly control disturbing activities other than disaster prevention and control, ecological conservation and restoration, and historic site protection.
Middle-Security Pattern	190.3km^2 (15.8%)	Buffer forest zone, coastal wetland, pond water surface, geological hazard buffer zone, park green space, field open space resources	As a buffer area of low-security pattern, it is mainly for protection and restoration, and as an isolation zone, recreational activities can be carried out moderately.
High-Security Pattern	157.5km^2 (13.1%)	Small rolling hills, seasonal stream waterways, washouts scattered farmland around construction sites, road traffic, scattered green spaces within the city	The flexible control area allows reasonable and moderate agricultural production activities and urban and rural development and construction.

3.2. Spatial Identification and Strategies for Ecological Restoration

The low-security level areas in the integrated landscape safety pattern of Liangjiang New Area were overlaid with the spatial distribution of construction land in 2018 to identify the damaged ecological spaces (Figure 7), and the conflicting spaces were used as the basis for carrying out ecological restoration work. It can be found that the spatial conflicts between the low-security pattern and the construction land are mostly distributed in the edge zone of the built-up area and the junction of the Yangtze River and Jialing River with the built-up area, including the west side of the Yulin River in Longxing Town, the east side of Tongluo Mountain in Yuzui Town along Chang'an Avenue and Luyu Expressway, along the Jialing River from Shimahe Street to Jiangbei City Street, and along the Jialing River in Yuelai Street. Other conflict areas are small, scattered, and close to reservoirs, parks and other ecological infrastructure. For the damaged ecological space, according to the ecological restoration principle of overall protection and systematic management, the following ecological restoration strategies are proposed with comprehensive consideration of each element of the ecosystem and emphasis on the connectivity, systemic and integrity of the ecological pattern.

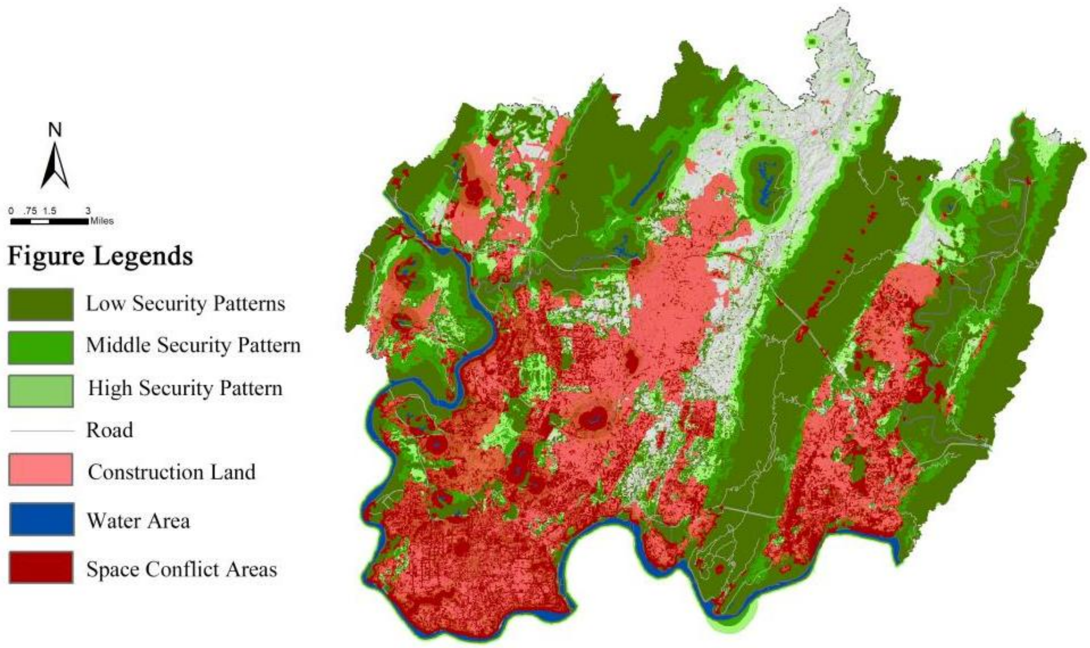

Figure 7. Ecological conflict space in Liangjiang New Area. Source: Drawn by author.

(1) Safeguarding ecological space and maintaining biodiversity.

Strictly control construction activities that are incompatible with the main functions of ecological source patches, increase the efforts of forest and mountain conservation, etc., and maintain the original topography and biodiversity. With natural restoration as the main focus and artificial restoration as a supplement, ecological restoration projects such as returning farmland to forests, lakes and grasses are implemented to enhance the function of natural ecosystem (Jiao, et al.,2021). At the same time, given that ecological conflict spaces are mostly distributed at the edges of built-up areas, it is necessary to strengthen the control of the edges of ecological source patches and focus on the construction of ecological buffer zones to avoid urban development and construction from breaking through the ecological bottom line. As for the ecological conflict spaces caused by large traffic roads blocking the connection of ecological source sites, emphasis should be placed on setting up culverts, flyovers and other biological channels to ensure smooth and safe biological flow.

(2) Ensure the safety of water bodies and strengthen shoreline control.

Ensure the safety of the river, to strengthen shoreline control and coastal wetland protection, restore the natural form and topography of the river, plant ecological protection forests along the shoreline, restore the ecological function of the shoreline. Strictly limit illegal construction projects, gradually withdraw from the land and industry incompatible with ecological functions, carry out shoreline regreening, create ecological berms and recreational facilities, improve waterfront landscape and flood control safety.

(3) Optimize green space structure and enhance recreational experience.

For the fragmented and scattered ecological conflict space, ecological land can be reorganized through relevant planning. For example, measures such as off-site re-greening and off-site afforestation are taken to integrate green space resources, while strengthening the construction of green belts and green centers to gradually restore the continuity of green space systems. Combined with local cultural resources, the form and content of green space can be enriched to enhance the characteristics of urban landscapes and improve the public recreation experience.

(4) Abatement of geological hazards and implementation of dynamic monitoring.

It is necessary to conduct geological examination of the actual local situation and determine the degree of risk and the size and scope of hazards of geological hazards under different geological conditions, so as to tailor the measures to local conditions and the hazards. Relocate and resettle farmers seriously affected by geological disasters and strengthen the dynamic monitoring of geological disasters such as landslides, unstable slopes and mudslides. Simple engineering is used to treat geological hazards with certain risks (Chang, et al.,2021; aghipour, et al.,2016), such as reducing cave-in by ground subsidence techniques, planting reclamation to reduce soil erosion, etc. For geological hazards with potential risks, the sites are evaluated and the types of land use are reasonably arranged.

4. Conclusion

Based on the theory of landscape ecological security pattern, this paper applies the least resistance model, and with the technical support of GIS and RS spatial analysis, identifies the security pattern of geological hazards, hydrological system, vernacular culture and biological protection in Liangjiang New Area, then superimposes various ecological security patterns to build a integrated landscape safety pattern and divides three types of ecological security zones: low-security pattern 626.5 km^2 accounts for 52.2% of the total area of the region, which is the bottom line to ensure regional ecological security; medium-security pattern 190.3km^2 accounts for 15.8% of the total area of the region, which is the suitable scale for regional ecological process; high-security pattern 157.5km^2 accounts for 13.1% of the total area of the region, which is ideal for ecological service function within the sub-region. Finally, the integrated landscape safety pattern is overlaid with the construction land to identify the ecological restoration space of Liangjiang New Area, and four ecological restoration strategies are proposed to safeguard ecological space and maintain biodiversity, ensure water safety and strengthen shoreline control, optimize green space structure and enhance recreational experience, and reduce geological hazards and implement dynamic monitoring.

The study is based on the landscape ecological safety pattern, coupling the static landscape pattern and dynamic ecological processes together to provide scientific and effective spatial guidelines for urban ecological restoration. However, there are still some shortcomings in the study. The four ecological processes of geological hazards, hydrological system, vernacular culture and biodiversity are selected to build the landscape safety pattern, but the ecological service functions of ecological infrastructure also include many kinds (such as climate regulation), and a more detailed system of ecological safety pattern is worthy of in-depth study. In addition, the resistance factors and assigned values in the landscape resistance surface constructed by the minimum resistance model, the authors referred to relevant research results at home and abroad and selected representative resistance factors to construct the resistance surface, and in the future, it is necessary to develop more accurate and reasonable resistance values by combining the characteristics of the study area and ecological processes to improve the scientific nature of the model operation.

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