Constructing and optimizing ecological network at county and town scale: The case of Shilin County, China

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Abstract
High-intensive land development had led to increasingly fragmented urban habitat patches, and the contradiction between regional development and ecological protection is gradually intensified. This ecological problem is spreading from cities to counties and towns, which are mainly villages and towns. Constructing a reasonable ecological network is an effective way to connect fragmented habitats and balance regional morphological and spatial patterns. Taking the Shilin County of the Yunnan province, China as the study area, morphological spatial pattern analysis and connectivity analysis were used together to identify the key ecological source areas and their importance levels. The comprehensive resistance surface based on the migration characteristics of terrestrial animals was assembled based on five variables (altitude; slope; distance to road; distance to population centers; land use map). The gravity model was used to identify the priority of the ecological corridors, and the ecological networks was derived. The results show that the initially constructed ecological network includes 11 ecological sources and 26 ecological corridors, of which seven are important ecological corridors that need priority construction. However, the ecological networks were less distributed in the northern regions, so three supplementary ecological sources and ten supplementary ecological corridors were added to optimize the ecological network. In addition, there are significant differences in the size and number of ecological source sites and corridors between townships, and targeted construction strategies are necessary. The in-depth analysis from county to township makes the construction and management of ecological networks more maneuverable in national administration. This study provides guidance for constructing ecological network structures in townships with complex landscape types, and may also provide lessons for other regions. Through an in-depth analysis from county to town, this study can provide guidance to construct the township ecological network structure with complex landscape types and provide reference for other regions as well.

Introduction
In recent years, rapid urban expansion and high-intensity land expansion on a global scale have led to a series of ecological problems such as reduced biodiversity and increased landscape fragmentation (Baloch et al. 2019; Dai et al. 2020; Song et al. 2014). Worldwide, especially in areas with high urbanization rates, these problems can directly affect the sustainable development of that city and pose serious threats to the survival of flora and fauna and the human habitat (Kattel et al. 2013). Therefore, how to resolve the conflict between economic development and ecological security is a global imperative (Wu et al. 2020). The construction of ecological networks aims to effectively link fragmented habitat patches to form a spatially integrated network of landscapes and habitats, thereby improving the quality of natural ecosystems and conserving biodiversity (Xiao et al. 2020).

Establishing ecological network is an effective way to maintain ecological security and protect biodiversity (Lookingbill et al. 2010; Montis et al. 2016). An ecological network consists of three landscape elements: ecological sources, ecological corridors and ecological nodes (Graham et al. 2006). It is an organic continuous network system in space by linking landscape elements in the region with
corridors as the main line (Cunha et al. 2019; Sun et al. 2018). The ecological network pattern reflects the spatial organization pattern of fragmented habitats and the linkage of species survival, and is the spatial basis for the delineation of important functional areas such as ecological red lines and urban development boundary lines (Xiao et al. 2019).

A large number of studies have provided a more mature research paradigm for ecological network construction and a reference for ecological restoration in the national space. Different scholars tend to choose different methods to identify ecological source sites, construct ecological resistance surfaces and extract ecological corridors. Currently, the commonly used methods are minimum cumulative resistance model (Guan et al. 2022; Ye et al. 2020; Kong et al. 2010), graph theory method and circuit theory are the more common research methods. For example, Alexander provides relatively safe ecological corridors for the migration of spectacled bears through the minimum resistance model and the potential distribution model of spectacled bears (Sánchez et al. 2022); Di Zhou achieves the identification of potential ecological corridors and the construction of ecological networks in Chongqing through linkage mapper (Zhou et al. 2021). Peng combines circuit theory and linkage mapper to construct ecological networks in Yunnan Province (Peng et al. 2018). However, most of the above studies focus on the macroscopic scale above the county level, and relatively few studies are conducted on the county and town scale. And most of the ecological network studies in China have relatively stable study areas, and it is still debatable whether they are applicable to the relatively complex Shilin County karst landscape (Zhao et al. 2022).

The basic research model of ecological network identification has been formed as "ecological source identification - resistance surface construction - ecological corridor extraction" (Miao et al. 2019).

Counties in China are the basic units for formulating and implementing land use policies, and are important spatial carriers for promoting urbanization. In current studies, most scholars focus their attention on the provincial level, and thus there are problems such as fragmentation and difficulty in linking ecological network plans at the county level with each other. These add difficulties to the integrated implementation of planning, and therefore need more attention and research.

Materials And Methods

1 Study region

Shilin County is located in Yunnan province's Middle East. The geographic coordinates are 103°10′~104°N,24°30´~25°03E, with a total area of 1719 km² (Fig. 1). The study area is mostly mountainous, accounting for 69%. The area belongs to the plateau mountain monsoon climate, and holds the Paleozoic karst landform community stone forest with the longest karst landform evolution history, the widest distribution area, complete types and unique shape in the world. However, in the current stage of rapid development of the tertiary industry, the high intensity of human activities has led to reduction in ecological land, habitat fragmentation, weakened ability of ecological regulation (Cheng et al. 2018; Carrete et al. 2009).
2 Data sources

The main data adopted in this study are the remote sensing images of 2020 with a resolution of 30m * 30m (http://www.bigemap.com), the DEM (Digital Elevation Model) data of the Shilin region (http://www.gscloud.cn), and vector data for the road network (http://www.bigemap.com), and vector data for the settlement (http://www.bigemap.com). ENVI software was used to supervision and classification the image data in the study area based on visual interpretation, and the land use classification map of the study area with a grid size of 30m*30m was finally obtained. The main types of land use data involved eight categories (forest, farm land, grassland, wetland, garden plot, road land, built-up land and else). All data use similar years to ensure scientific results, and all data are unified into the GCS_WGS_1984 geographic coordinate system and the WGS_1984_UTM_Zone_48N projection coordinate system.

3 Constructing ecological network

3.1 Identification of ecological sources

The MSPA (Soille et al. 2009) classification routine based on defining connectivity and edge width, changing the subjectivity of previous artificial ecological source selection to a certain extent (Vogt et al. 2009; Wickham et al. 2010). In this study, the classified first-level land types were reclassified. Forest, grassland, garden land, and wetland, which were less affected by humans and had high ecological service functions, are extracted to be the foreground, and the rest as the background (Peter et al. 2017). Based on the eight-neighborhood analysis method and the Guidos Toolbox software, a tiff format binary grid data are measured, identified and segmented, and interpret seven mutually exclusive landscape types (core areas, bridges, edges, branches, loops, islands, and perforations)(Fig. 2)(Zhang et al. 2020).

The level of landscape connectivity in a region can quantitatively characterize whether a certain landscape type is suitable for species exchange and migration, which is of great significance for biodiversity protection and ecosystem balance (Sun et al. 2013).

At present, in the aspect of landscape connectivity evaluation, the probability of connectivity (PC, Equation (1)), and the delta of PC (dPC, Equation (2)), are commonly used as the important indicators of landscape pattern and function, which can reflect well the degree of connection between core patches in the regional level (Cook 2002; Ye et al. 2020). The specific formula is defined as follows:

\[ PC = \sum_{i=1}^{n} \sum_{j=1}^{n} a_i \cdot a_j \cdot p_{ij} / A^2 \]

\[ dPC = \frac{PC - PC_{\text{remove}}}{PC} \times 100\% \]
where, \( n \) is the number of patches within the research range; \( a_i \) and \( a_j \) are the areas of patches \( i \) and \( j \); \( p_{ij} \) is the maximum probability of species dispersion in patches \( i \) and \( j \); \( dPC \) represents the importance of the removed element, \( PC \) is the calculation result of connectivity; and \( PC_{\text{remove}} \) represents the calculation result of connectivity after the removal of a certain element.

This study relies on the delta of PC (dPC) as an important indicator for selecting ecological sources. Quantitative evaluation of core area and bridges extracted by MSPA based on Conefor software. The top 30 patches in the core area and the patches with dPC value greater than 5 are regarded as important ecological sources (Carlier et al. 2018; cheng et al. 2020). Ecological patches with dPC>20 were designated as important habitats, 10<dPC\( \leq \)20 as medium habitats, and 5<dPC\( \leq \)10 as general habitats (Zhang Yu et al. 2016). Combining the patch area and possible connectivity index to rank the importance of ecological sources can provide a scientific basis for the construction of ecological spatial network in Shilin County.

### 3.2 Constructing the resistance surface

The construction of ecological infrastructure needs to consider the comprehensive effects of substrates on ecological processes. Based on the expert scoring method and AHP method (Moilanen A et al 2001), five factors, namely elevation, slope, land use type, distance from the road, and distance from the settlement, were selected to develop five rating variables in this paper. Referring to the relevant studies, the resistance values of each resistance factor are selected in Table 1 (Shi et al. 2020; Zimmermann et al. 2007; Zhang et al. 2020).

**Table 1** Score and weight of resistance factors
<table>
<thead>
<tr>
<th>Resistance Factor</th>
<th>Classification Index</th>
<th>Evaluation</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation(m)</td>
<td>&lt;1800</td>
<td>1</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>1800-2000</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000-2200</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2200-2400</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;2400</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Gradient(°)</td>
<td>&lt;5</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>5-10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10-15</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15-20</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;20</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Grade of the road</td>
<td>Expressway</td>
<td>9</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Secondary Roads</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tertiary roads</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class IV Roads</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Distance from residential area(m)</td>
<td>&lt;500</td>
<td>9</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>500-1000</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1000-1500</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3500-5000</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;5000</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lands use</td>
<td>Grassland, Garden plot, Cultivated land</td>
<td>1</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>Forest</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wetland</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Else</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Built-up land, Road</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Extract and graduate potential ecological corridor

The minimum cumulative resistance model approach determines the optimal pathway for species migration and dispersal by calculating the minimum cumulative resistance distance between the source...
and the target. The method effectively avoids all forms of external disturbances (Chen et al. 2020; Groot et al. 2010). Based on the GIS platform, each weight coefficient was weighted and superimposed with each resistance factor to obtain a comprehensive resistance surface to represent the cost data of the minimum resistance model in Shilin County. A total of 55 potential ecological corridors were generated through the cost paths in GIS. The formula of MCR model is as follow:

$$MCR = \min \sum_{p=m}^{n} (D_{pq} \times R_p)$$

Where $D_{pq}$ represents the spatial distance from the source point q to the space until p and $R_p$ represents the resistance coefficient of space until p.

The interaction intensity can be constructed based on the gravity model to quantitatively evaluate the interaction strength between habitat patches and identify the relative importance of potential corridors (Xu et al. 2015). According to the matrix and the current situation of the study area, the extracted corridors were modified, and the corridors with $F_{ij}>2$ were selected as primary corridors, $1<F_{ij}<2$ as secondary corridors, and $F_{ij}<1$ as tertiary corridors by removing duplication and crossover. The formula is as follow:

$$F_{ij} = N_i N_j / D_{ij}^2 = L_{ij}^2 \ln (a_i a_j) / L_{ij}^2 P_i P_j$$

Where: $F_{ij}$ is the interaction force between source i and source j, $N_i$ and $N_j$ are the corresponding weight values of i and j, $D_{ij}$ is the standard value of corridor resistance between i and j, $L_{max}$ is the maximum value of all corridor resistance in the study area, $a_i$ and $a_j$ are the areas of i and j, $L_{ij}$ is the value of corridor resistance between i and j, and $P_i$ and $P_j$ are the average resistance values of i and j.

In summary, the flowchart of this study's analysis and procedures is as follows (Fig. 3).

### 3.4 Optimize ecological network

In the ecological network constructed based on the MCR model, some areas will have missing ecological source sites and corridors. This study uses the patch area as a reference, and selects patches with larger patch area as supplementary source sites in the missing ecological source sites, which can effectively solve this problem.

Stepping stones, as a transit point for biological migration, not only increase the connectivity between ecological source sites but also increase the frequency of species activities between patches, ensuring the stability of ecological networks (An et al. 2020; Cook et al. 1991; Saura et al. 2014). In this study, stepping stones were installed according to the intersection of ecological corridors to increase the connectivity between source sites.
The migration of reptiles is hindered by land traffic. This study provides a reference for corridor restoration and ecological network optimization by selecting the intersection of primary corridors and major traffic arteries as ecological breakpoints.

**Results**

**Spatial and scale distribution of ecological patches**

From the MSPA analysis, it can be seen that the landscape area of the foreground data is 90,110.25 hm$^2$ (Table 2), accounting for 53.62% of the total area of the study area. The core area was 46936.17 hm$^2$, accounting for 52.09% of the foreground data, which was mainly distributed in the central, eastern and western parts of the study area, in an aggregated state with a large area. The northern patches are smaller and scattered. The edge area is 16,666.65 hm$^2$ and the perforation area is 2,359.80 hm$^2$. Both serve as the peripheral and internal protection barriers of the core area, accounting for 18.5% and 2.62% of the total woodland area, respectively. The area of the two is second only to the area of the core area in terms of size, which reduces to a certain extent the related disturbance caused by external factors to the core area. The branch, which accounts for 8.37% of the total ecological landscape surface, plays a connecting role in the study area, reflecting to some extent the existence of interruptions in the continuity of ecological corridors in the study area. The loop and bridge, as the channels for species migration and energy flow within and adjacent to the core area, only accounted for 3.27% and 10.71% of the total ecological landscape surface, indicating that there are fewer original ecological corridors in the study area. The islet play the role of stepping stones in the whole ecological network, occupying a smaller proportion and a more fragmented distribution, accounting for only 4.46% of the total ecological landscape area.

**Table 2** Statistics of landscape types based on MSPA

<table>
<thead>
<tr>
<th>Landscape type</th>
<th>Area(hm$^2$)</th>
<th>Accounted for area of ecological land (%)</th>
<th>Accounted for area of county(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>46936.17</td>
<td>52.09</td>
<td>27.93</td>
</tr>
<tr>
<td>Islet</td>
<td>4014.99</td>
<td>4.46</td>
<td>2.39</td>
</tr>
<tr>
<td>Perforation</td>
<td>2359.8</td>
<td>2.62</td>
<td>1.4</td>
</tr>
<tr>
<td>Edge</td>
<td>16666.65</td>
<td>18.5</td>
<td>9.92</td>
</tr>
<tr>
<td>Loop</td>
<td>2942.82</td>
<td>3.27</td>
<td>1.75</td>
</tr>
<tr>
<td>Bridge</td>
<td>9646.29</td>
<td>10.71</td>
<td>5.74</td>
</tr>
<tr>
<td>Branch</td>
<td>7543.53</td>
<td>8.37</td>
<td>4.49</td>
</tr>
<tr>
<td>Total</td>
<td>90110.25</td>
<td>100</td>
<td>53.62</td>
</tr>
</tbody>
</table>
In order to make the operation of ecological network a reference for local administration, this study analyzed the distribution of patches at the town scale. From the results of MSPA and landscape connectivity analysis, it can be seen that important ecological habitats in Shilin County are mainly distributed in Guishan Town, which is the main distribution area of ecological protection land with rich biological resources and high landscape connectivity. Medium habitats are mainly distributed in Changhu Town and Xijiekou Town; Banqiao Street Office is the second. The area of ecological source land in the area of Shilin Street Office, Dake Township and Lufu Street Office is smaller, the patches are more fragmented, and the importance of the patches is smaller compared to the east. The eastern part of the study area has a larger ecological source area and the importance of the patches is much higher than the other areas, indicating that the ecological environment in this area is better, while the western and central parts are the second. However, the landscape connectivity in the northern part of the study area, including Shilin and Lufu street offices, is low, and the small size of the patches is not conducive to the migration and dispersal of species, so the construction of this area needs to be strengthened.

Construction of ecological resistance surface

The ecological resistance surface was calculated according to the weight of each factor (Fig. 4(a-e)). Based on figure 4-(f), the resistance show a trend of increasing from the central part of the county to the outside. The lower resistance area are mainly located in the central and southern parts of the county, mainly because of the abundant woodland resources in the central and southern mountainous areas of the study area, so the resistance are lower, indicating that species migration is easier. The high resistance areas were mainly in the built-up areas, such as the Lufu street Office and the northern part of the Shilin Scenic Area, where the concentration of construction land and strong human interference factors led to high ecological resistance in local areas. Considering that, generally, species choose paths with lower resistance for movement and migration, the cumulative resistance surface provides a data basis for the construction of an ecological networks.

Construction of ecological networks based on MCR model

Based on the MCR model, the interactions between the source patches were quantified and 26 ecological corridors were identified, and the ecological network was obtained after eliminating some redundant corridors. The corridors were classified into 3 levels by the quantitative analysis of the gravity model. The patches with interaction forces greater than 3 are classified as important potential corridors, with a total of 7, medium potential ecological corridors between 1 and 3, and the interaction forces between 0 and 1 are classified as general potential ecological corridors. As shown in the figure5, the strongest interaction is between patches 9 and 10. Between these two patches, biological species are more likely to overcome resistance to migration, so the protection of this corridor should be strengthened to avoid losses due to the expansion of construction land. The distance between patches 2 and 5 is the farthest, and material exchange takes longer costly distances, so energy transfer is more difficult.
Optimize the ecological network

Through the quantitative analysis of the gravity model, this study combined with the current situation of the study area and can be known that the northern part of the study area has a lack of ecological source land and poor ecological function due to the large area of land for construction and agricultural facilities. Considering the demand for ecological source sites for terrestrial species migration, according to the core area distribution obtained from MSPA analysis and combined with the corridor distribution, the selection of new source sites was prioritized based on area. In this study, three patches were selected as supplementary ecological source to balance the ecological source layout. As shown in the figure 5, the three additional ecological source effectively bridge the gap between the northern and southern areas of the study area. The total area of the supplementary patches is 23.62 km$^2$ and forms a new ecological network together with the additional 139.73 km of ecological corridors. Roads, as high resistance factors in the migration of terrestrial species, are prone to breakage at the intersection with the corridors, resulting in impaired landscape functions and playing a strong interference to the migration of species and biomass exchange. In this study, a total of 13 ecological break points were identified through the overlay of road networks and ecological corridors. In the process of ecological network construction, underpasses and tunnels can be constructed at ecological breakpoints for breakpoint restoration as a way to improve the landscape connectivity in the study area. Since some of the corridors in the study area are long in length and play an obstructive role in the migration of plants and animals, the intersection points of the corridors are taken as stepping stones in this study to provide a short resting space for the migration of plants and animals. A total of 26 stepping stones were selected in this study. The land type of stepping stones in the central and southern areas is woodland, and their ecological quality can be improved by planting young forests and designating ecological reserves. In the north, the ecological function is poor due to the high ecological resistance, and the land type of stepping stones is mainly agricultural land with large human interference. Therefore, isolated forest strips can be established to improve the habitat quality. The protective forest understory consists mainly of thorny shrubs to reduce anthropogenic disturbance. Internal agricultural land is selected for crops that require less management.

Discussion

Core Area Selection Based on MSPA Models

Although Shilin County is rich in land use types and forms different landscape patterns, the spatial distribution of ecological source and corridors in the study area is unbalanced at the township level. In particular, patches are missing in the northern part of the study area due to human activities. Therefore, the construction of core in the north should be strengthened. Since MSPA is highly sensitive to the study scale of the landscape, data at different scales will produce different study results. In this study, the granularity of 30*30m and the edge width were set to 1 according to the default value based on related literature, but the threshold value was not applicable to all species (Rosot et al. 2018; Hernando et al. 2017). The size of MSPA should be further discussed, and different spatial scales should be selected for
comparative analysis. The habits of local protected species can also be incorporated to analyze and discuss from different perspectives.

**Analysis of Landscape Connectivity**

Based on area ranking and PC, 11 ecological source patches were selected to classify them as critical habitats, medium habitats and general habitats. The critical habitats in Shilin County are mainly located in the eastern part of the study area, such as GS and XJK. These patches have richer landscape resources and stronger inter-patch connectivity, which are more conducive to the migration of biological species and the exchange of materials and energy. They should be focused on protection in the future development and construction. In contrast, the general habitat and medium habitat are mostly located in the central and western parts of the study area, especially in the central part, where the core patches are small and fragmented. In general, the protection of critical habitats should be strengthened, while the construction of medium and general habitats should be combined with the ecological status of the regions in which they are located to give full play to the economic, social and ecological benefits.

**Construction of Shilin’s Ecological Network**

In this study, ecological breakpoints and stepping stone were identified by superimposing the intersection of road networks and ecological corridors, then, ecological sources, corridors, nodes, and breakpoints were superimposed to generate an ecological network in Shilin County. The eastern part of the study area has more dense ecological corridors and nodes, in contrast to the western part. Shilin County has brought enormous pressure on the ecological environment due to highly intensive land development, and the landscape is severely fragmented. The ecological network provides the best path choice for species migration and material exchange, and improves ecological service functions to a large extent. In addition, constructing ecological networks requires not only strong support from government policies, but also financial support. The Chinese government should increase its investment in the construction of the ecological network in Shilin County based on the existing protected areas, by formulating relevant policies and increasing investment in greening the landscape.

**Conclusion**

Urbanization, as an important driver of land degradation, has caused serious environmental disturbance and ecological degradation. And identifying and optimizing ecosystems is a pragmatic way to resolve the conflict between urban development and ecological protection. This study takes the landscape ecological security pattern of Shilin County as the main elements, ecological sources, ecological corridors and ecological nodes as research objects, to construct the landscape ecological security pattern of Shilin County and provide a scientific basis for how to alleviate the contradiction between urban development and ecological conservation.
In this study, 11 important ecological sources were identified using MSPA and MCR based on satellite image data 26 potential ecological corridors were constructed based on MCR model and gravity model. Finally, the ecological network was optimized based on the current situation of the study area to address the existing problems. After optimization, 3 new ecological source and 8 ecological corridors were added. Ecological breakpoints and stepping stone were identified by superimposing the intersection points of road networks and ecological corridors, and finally the ecological sources, corridors, nodes and breakpoints were superimposed to generate a new ecological network in Shilin County. The results show that: 1). The landscape composition of Shilin County is dominated by woodland, grassland and framland, but mainly distributed in the central and southern part of the study area. The area of ecological source in the study is small, accounting for 12.53% of the total area of the county. Ecological sources and ecological corridors are unevenly distributed, especially in the northern part of the study area where ecological source sites are missing. Therefore, 3 ecological sources and 8 ecological corridors were added to the northern part of the study area to balance the ecological network distribution. 2) Important ecological corridors are mainly located in the central and southern parts of the study area. Considering the demand for ecological sources for terrestrial migration and alleviating the conflict between economic development and ecological protection among town, stepping stones and ecological sources are added in SL. This initiative increases the implementability of the ecological network at the county level and clarifies the responsibility of ecological construction among the townships.

Declarations

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Ethical approval NA.

Consent to participate NA.

Consent for publication All authors have provided consent to publish.
References


Figure 1

Geographical location of Shilin County, China
Figure 2

Landscape type map of Shilin County generated via Morphological Spatial Pattern Analysis
Figure 3

Flowchart of the analysis and research procedures in this study
Figure 4

a elevation resistance surface b land use resistance surface c slope resistance surface d road resistance surface e residential resistance surface and f accumulated resistance surface obtained for Shilin County
Figure 5

Optimized ecological corridor and its data statistics at town scale.