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Research Article

Ecological Importance Evaluation of the Changzhutan Ecological Green Heart

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The ecological source area is the basis of regional ecological security, clearing the important performance of the ecological source area in the region to provide targeted measures for ecological construction. Taking the Changsha-Zhuzhou-Xiangtan ecological green core as an example, the ecological importance evaluation system was constructed from five aspects of spatial location, scale advantage, spatial layout, spatial connection, and ecological composition. For the spatial structure based on ecological networks, the ecological importance evaluation was carried out, and the ecological function was defined. It can provide a reference for the protection and construction of the Changsha-Zhuzhou-Xiangtan ecological green core. The results show the following: (1) The research method of inferring the ecological functions of ecological source sites based on the spatial characteristics of ecological networks and then completing the evaluation of ecological importance is feasible and effective, reflecting the macroecological functions played by ecological source sites in regional ecosystems and providing ideas for exploring the multiple ecological functions of ecological source sites from a combination of macro and micro perspectives. (2) The ecological importance of the Changzhutan Ecological Green Center is much higher than other ecological sources in Changzhutan Urban Cluster, and its main ecological function is the spatial structure strengthening function, followed by the spatial connection function, and the ecological service function is lower. The internal landscape pattern of interlocking arable land and woodland, with arable land blocking the ecological landscape, requires landscape pattern optimization. (3) The ecological green heart of Changzhutan is close to the regional mass center, and the ecological service area accounts for 14.57% of the area of Changzhutan urban agglomeration, which is connected to 55% of the ecological sources through ecological corridors, is the core hub connecting the north-south ecosystem of Changzhutan urban agglomeration, and is in a dominant position in the regional ecosystem. In the absence of the Changzhutan ecological green heart, the patch density, average proximity, cohesion, and aggregation all drop to the lowest, connectivity drops to the second lowest, and subdimensionality reaches the highest, highlighting the significance of the Changzhutan ecological green heart to maintain the ecological green volume of the Changzhutan urban cluster, enhance the overall ecosystem connectivity, and reduce landscape fragmentation. (4) There are five important ecological connection points between the Changzhutan Ecological Green Center and external ecosystem, which need to take different measures to strengthen ecological protection and construction.

1. Introduction

Ecological source sites are the main carriers of the generation and development of natural ecological processes in the ecosystem and are the landscape components that mainly perform ecological service functions in a specific area [1, 2]. The ecological process is the process of material cycle and energy conversion in the ecosystem, which controls the direction of ecosystem succession [3]. Therefore, it is necessary to clarify the ecological functions of ecological sourcelands, highlight the ecological importance of ecological sourcelands, and protect and construct ecological sourcelands in a targeted manner. The concept of ecological sourceland originated from the idea of land classification based on natural ecosystems and resources in the United States in 1915 [4], mainly for natural ecosystems where wild plants and animals gather, but the boundary concept of ecological sourceland is vague, and its connotation has limitations [5]. In the 1960s, the concept of ecosystem services was gradually formed [6], and the concept of ecological sourceland was extended to composite ecosystems and spatial units [7], forming areas with significant ecological benefits and boundary concepts such as nature reserves and nature parks, and the research content was extended to ecological function evaluation and ecological zoning [8–11]. As the research on the interrelationship between landscape patterns and ecological processes continues to deepen, the idea that there are important localities in ecosystems that play a key controlling role in ecological processes is gradually formed; the method of simulating the interaction between landscape patterns and ecological processes based on ecological resistance and then constructing ecological networks becomes an important method to protect ecological environments and optimize landscape patterns; and ecological source sites, as the basis for ecological network construction, are ecologically important. The ecological importance of ecological source sites as the basis of ecological network construction has further increased and become the core part of regional ecosystems [12–14].

The ecological importance of ecological source sites is mainly reflected in their ecological functions [15, 16]. At present, the research oncological functions of the ecological source area are mainly combined with microecological functions. This includes water connotation, biodiversity conservation, and purification function, while there are fewer studies analyzing the ecological functions of ecological source sites from a macroscopic perspective [17–19]. The reasons for this are, on the one hand, that regional geographic information is refuted and it is difficult to clarify the important ecological functions played by ecological source sites in regional ecosystems; on the other hand, it is difficult to quantify the ecological functions of ecological source sites from a macroscopic perspective. Ecological network construction is a method of connecting important landscapes in an ecosystem into a network by exploring the degree of obstruction of ecological processes by landscape patterns from a regional perspective, with ecological source sites as the core, and identifying the “key localities” that control ecological processes in the ecosystem [20, 21]. The spatial structure of the ecological network is characterized by the geographic information and spatial location of the ecological source sites. Therefore, it is beneficial to examine the ecological source sites from the perspective of the ecological network in reverse, so that we can explore the ecological functions played by the ecological source sites in the regional ecosystem from a macroscopic perspective and evaluate the ecological importance of the ecological source sites.

The Changsha-Zhuzhou-Xiangtan region is an important urban development group in central China, including Changsha, Zhuzhou, and Xiangtan, which is one of the core growth poles of economic development in central China and has an important impact on the development of the Yangtze River Economic Zone. In recent years, the rapid development of economy and society and the acceleration of the urbanization process have led to heavy metal pollution of land, vegetation degradation, encroachment of ecological sources, and other issues, which seriously hinder the coordinated development of economy and society in the Changsha-Zhuzhou-Xiangtan region [22]. The Changsha-Zhuzhou-Xiangtan ecological green core (hereinafter referred to as ecological green core) is located in the center of Changsha-Zhuzhou-Xiangtan urban agglomeration, close to the built-up areas of the three cities, shouldering the important task of ecological core and ecological barrier. With the economic and social development, urban construction has gradually penetrated into the ecological green heart, the ecological environment has been damaged, the ecological landscape has been exploited and occupied, and the ecological service function of the ecological green heart has been reduced. Therefore, it is necessary to explore the important ecological functions of the ecological green heart in the Changzhutan city cluster and highlight the ecological importance of the ecological green heart, so as to protect and construct ecological green heart in a targeted way and guarantee the ecological security of the Changzhutan city cluster.

2. Research Area

The Changzhutan city cluster, with a total area of 28105.74 km^2, is located in the central-eastern part of Hunan Province, China, and is an important part of the middle reaches of the Yangtze River city cluster, including Changsha, Zhuzhou, and Xiangtan, which is the core growth pole of Hunan Province’s economic development. In 2007, the Changzhutan city cluster was approved as a comprehensive supporting reform pilot area for the construction of a resource-saving and environment-friendly society in China. However, Changzhutan urban agglomeration is in the key area of agricultural production in China’s ecological function zoning, with a large amount of arable land and wide distribution area, coupled with the rapid development of Changzhutan urban agglomeration in the past 20 years, the construction land and transportation land occupy a large area of woodland, water, and other ecological landscape, the number of ecological landscape in Changzhutan urban agglomeration decreases year by year, the ecological landscape is gradually separated in space, and land development and utilization have penetrated into the natural ecosystem. Ecological protection is urgent. Under the background of two themes of development and protection, it is not only inconsistent with the requirement of coordinated development but also uneconomical and unreasonable to negate the built-up areas and implement ecological restoration on a large scale. Therefore, ecological protection should be based on the current situation, from the actual, targeted selection of key areas to implement ecological protection strategy, in order to keep the two lines of development and protection and promote the coordinated and sustainable development of the Changzhutan city cluster.

The ecological green core is located at the junction of Changsha City, Zhuzhou City, and Xiangtan City, between 112° 53′ 32″~113° 17′ 42″ east longitude and 27° 43′ 29″ ~28° 05′ 55″ north latitude, east to Zhentou Town, Liuyang City, south to Yisuhe Town, Xiangtan County, west to Baiquan Township, Changsha City, and north to Dongjing Street, Changsha City. The total area is 52788.65 hectares. The terrain in the territory is undulating, mainly hilly, with a relative height difference of 200 meters. The climate is subtropical monsoon climate, with abundant precipitation, rain, and heat in the same period, four distinct seasons, an annual average temperature of 17.2°C, and annual average precipitation of 1362 mm; vegetation type is mainly subtropical evergreen broad-leaved forest. Xiangjiang River runs through it from south to north, with abundant water resources with red soil and paddy soil as the main soil.

The ecological green heart is the green base of the central area of the Changzhutan city cluster. It is mainly composed of continuous forests, rivers, and farmland, including three forest parks and one scenic spot, with a special ecological location and remarkable ecological functions. However, the area where the ecological green core is located is an important agricultural production area in China, and the forest land and farmland landscape are interlaced with each other, while the urban built-up areas on both sides of the north and south continue to penetrate, causing obvious disturbance to the ecosystem and seriously affecting the ecological function of the ecological green center.

3. Data Sources and Research Methods

3.1. Data Sources and Processing. The basic data include the vector data of a land survey of three cities in Changsha-Zhuzhou-Xiangtan in 2019 provided by the Hunan Architectural Design Institute and the vector data of nature reserves in Changsha-Zhuzhou-Xiangtan in 2020 provided by the Hunan Forestry Bureau. The vector data are registered by geodetic 2000 coordinates in ArcGIS, and the vector data are preprocessed. Firstly, land types were classified into 8 landscape categories, including forest land, garden land, grassland, cultivated land, water area, transportation land, construction land, and other lands [11], and each landscape type was given ecological resistance value [11, 14] (Table 1). The second is to merge the spatially connected and overlapping nature reserves to form ecological sources.

3.2. Construction of the Ecological Network. Through the construction of the ecological network, the key part of the ecosystem in the study area was identified, which provided a basis for the analysis of the ecological importance of the ecological source. The ecological network is composed an of ecological source, ecological corridor, and ecological node. The steps of constructing the ecological network are as follows:

(1) Determining the ecological source area. The ecological source is the source of the ecological process, in order to protect the ecological environment for the purpose of landscape pattern optimization, the ecological source is the main ecological service function of the landscape unit in the ecosystem, these landscape units have to maintain their own ecosystem stability scale, and ecosystem natural degree is high, with mostly wild animals and plants habitat. This study includes forest parks, wetland parks, and other natural parks and nature reserves, with the ecological green heart as the ecological source

(2) Constructing an ecological resistance surface. An ecological resistance surface is a spatialized surface of a mathematical model used to simulate ecological processes. Landscape ecology holds that the flow of ecological material, energy, and information needs to overcome resistance, so the concept of resistance can be used to simulate the ecological process. Different landscape types have different resistance to the flow of ecological material, energy, and information. The ecological resistance of natural landscape types is small, while the ecological resistance of landscape types with serious human disturbance is large. Referring to the existing research, the ecological resistance of each landscape type is shown in Table 1. The arrangement and combination of landscape types in space constitute the landscape pattern, which has the corresponding ecological resistance. The landscape types were divided into cells according to a certain scale, and the ecological resistance of the landscape types per unit area was obtained. Then, the cumulative cost distance model was used to calculate the sum of the ecological resistance from any spatial position to the ecological source, and the ecological resistance surface was obtained. The movement mechanism of ecological flow in the landscape pattern was simulated, that is, the ecological process. The cumulative cost distance model calculation formula is as follows:

$$MCR = f_{\min} \sum \left(D_{ij} \times R_i \right) \quad (i = 1, 2, 3, \cdots, \mathrm{m}\,; \mathrm{j} = 1, 2, 3, \cdots, n), \tag{1}$$

where D_{ij} is the distance of the ecological flow from the landscape base to the source, R_i is the resistance value of landscape i, m is the number of landscape types, and n is the total number of basic units

(3) Calculation of ecological corridor. According to the biological tendency, the flow of ecological material, energy, and information always preferentially chooses the same or similar landscape type of the ecosystem and the ecological process, which is the tendency of the flow of ecological material, energy, and information. For example, when animals in the forest move from one habitat to another, they always preferentially choose the forest to pass through. Streams always flow from high to low. The flow of ecological material, energy, and information also

Table 1: Ecological resistance value and ecological service value of landscape types.

Landscape type	Forest land	Garden plot	Meadowland	Plough	Water area	Transport land	Construction land	Other land
Ecological resistance value (10000 Yuan/hm^2)	20	40	70	55	1	90	100	80
Ecological service value	3.78	2.52	0.82	0.48	24.52	0.00	0.00	0.03

tends to the path of low ecological resistance, and the path with the smallest cumulative ecological resistance value among all possible paths is the ecological corridor between ecological sources. The ecological corridor is the direct landscape entity connecting the ecological source to construct the ecological network, and it is the most possible landscape channel for the flow of ecological material, energy, and information, which plays an important role in maintaining the normal ecological process. The spatial analysis module of ArcGIS was used to calculate the ecological resistance cumulative cost path between the ecological sources, and the path with the minimum cost was the ecological corridor

(4) Identifying the ecological node. An ecological node is a landscape unit with a similar function to the ecological source, which is smaller than the ecological source and does not play a leading role in the ecological process. The ecological node is the ecological pedal between the ecological source, which provides a temporary stay area for the flow of ecological material, energy, and information. It is located in the fragile part of the ecological corridor and has the function of stabilizing the ecological corridor and promoting the ecological process. Because the cumulative ecological resistance from any position in space to different ecological sources is different, a line with equal cumulative ecological resistance value between two adjacent ecological sources is formed; the cumulative ecological resistance value on the line is the largest, the line is the path with the largest cumulative ecological resistance, it is bound to intersect with the ecological corridor, and the intersection point is the position with the largest ecological resistance on the ecological corridor. That is, the fragile point of the ecological corridor, that is, the ecological node

Based on the ecological source area, the ecological resistance surface of the study area was constructed based on the landscape type and ecological resistance value, and then the ecological corridor was calculated by using the cumulative consumption distance model to identify the ecological nodes, and finally, the ecological network was constructed.

3.3. Ecological Importance Assessment

3.3.1. Construction of Evaluation System. According to the theory of landscape ecology, the landscape has a scale effect, the landscape with a larger area has obvious advantages, has higher ecological stability, and has a greater impact on the ecosystem [23, 24]. The landscape has the characteristics of spatial location. The subecosystem in the center of the regional ecosystem exchanges material and energy with the surrounding subecosystems frequently and has a greater impact on the regional ecosystem than the subecosystem at the edge. Landscape pattern is formed by the spatial arrangement of landscape types and has the characteristics of horizontal spatial structure. The material, energy, and information in the ecosystem have mobility, and the ecosystem with good connectivity and high compatibility has a greater impact on regional ecological succession. Landscape types have different ecological service values and have different impacts on ecological processes. Based on the above theory, the study will evaluate the ecological importance of ecological green centers by selecting measurement indicators from five aspects: spatial location, scale advantage, spatial layout, spatial connectivity, and ecological composition (Figure 1). The principles for selecting the measurement indicators are as follows: (1) the measurement indicators can reflect the characteristics and essence of the evaluation object; (2) the measurement indicators can reflect the landscape pattern changes sensitively; (3) the data of the measurement indicators are accessible and can be quantified and compared; (4) the measurement indicators are independent of each other but have certain correlation; and (5) based on the dynamic changes of the landscape pattern, the direct measurement and the calculation of the landscape pattern index are combined. According to the principles of measuring index selection, the landscape pattern index is examined in FRAGSTATS from five aspects: spatial location, scale advantage, spatial layout, spatial connectivity, and ecological composition, combined with the spatial distribution characteristics of nature reserves in Changzhutan urban agglomeration. Eleven indicators including patch density (X_1), average proximity (X_2), connectivity (X_3), cohesion (X_4), fractal dimension (X_5), aggregation degree (X_6), centroid distance (X_7), proportion of the ecological service area (X_8), number of ecological source connections (X_9), average ecological service value (X_{10}), and number of animal and plant species (X_{11}) were selected to construct the model. In the evaluation system (Figure 1), the scale of the ecological source area is not repeatedly selected because of its high correlation with patch density. In the index system, patch density (X_1), mean proximity (X_2), connectivity (X_3), cohesion (X_4), fractal dimension (X_5), and aggregation degree (X_6) were used as landscape pattern indexes, which were calculated by FRAGSTATS. Centroid distance (X_7), proportion of the ecological service area (X_8), number of ecological source connections (X_9), average ecological service value (X_{10}), and number of animal and plant species (X_{11}) can be directly measured, counted, or analyzed by ArcGIS.

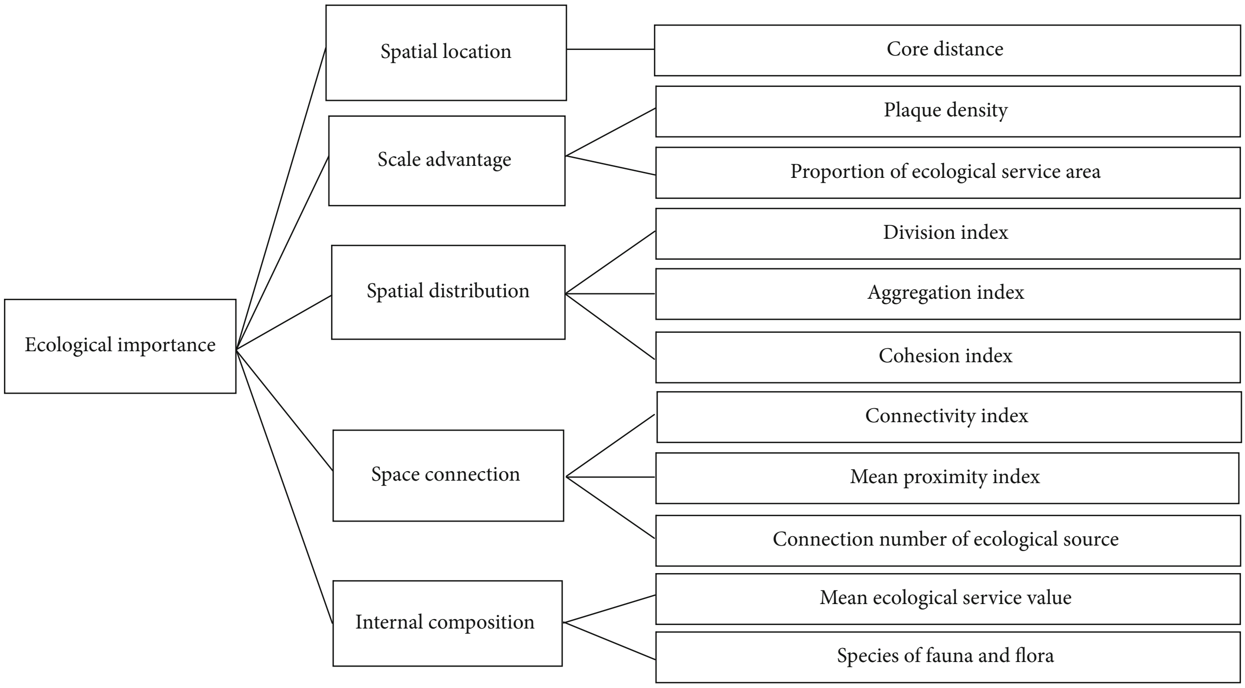

Figure 1: Evaluation system of the ecological importance of the ecological source area.

(1) Centroid Distances. The centroid distance is the distance from the geological center of the ecological source to the regional centroid to show whether the ecological source is in the regional center. The calculation formula is

$$D_i = \sqrt{(P_{zx} - P_{ix})^2 + (P_{zy} - P_{iy})^2}, \quad (2)$$

where D_i is the centroid distance of the ecological source i, p is the coordinate value, z is the regional centroid, x is the longitude coordinate, and y is the latitude coordinate.

The ecological service function of the ecological source area is to take it as the center to play around; in the case of the same ecological service function, the closer the ecological source area is to the regional center, the wider the coverage of its ecological service function, the greater the impact on the regional ecosystem, and the higher the ecological importance.

(2) Proportion of Ecological Service Area. The proportion of the ecological service area is the proportion of the ecological service area of each ecological source area. The calculation formula is

$$P_i = \frac{S_i}{S}. \quad (3)$$

In the formula, P_i is the proportion of the ecological service area of ecological source i, S_i is the area of the ecological service area of ecological source i, and S is the area of study area.

Under certain circumstances, the greater the proportion of the ecological service area in the ecological source area, the greater the impact on the ecosystem and the higher the ecological importance. The scope of the ecological service area is calculated by hydrological analysis. By using the ArcGIS hydrological analysis module, topographic analysis was carried out on the basis of the ecological resistance surface, the ridgeline was the path with the largest cumulative ecological resistance, and the closed area formed by the path with the largest cumulative ecological resistance was the ecological service scope of the ecological source.

(3) Number of Ecological Source Connections. The number of ecological sources connected by ecological corridors in the ecological network is the number of ecological sources connected. The more the number of connections, the more the ecological sources of impact, and then the greater the impact on the regional ecosystem, the higher the ecological importance.

(4) Average Ecosystem Service Value. The sum of the ecological service value of each landscape type in the ecological source area is counted, and then the average ecological service value is calculated. Generally, the landscape type with high ecological service value is conducive to ecosystem succession. The calculation formula is

$$V_i = \frac{\sum_{i=1}^{n} V_i A_i}{A}. \quad (4)$$

In the formula, V_i is the ecological service value of landscape type i, A_i is the area of landscape type i, and the A is the total area of landscape.

The higher the average ecological service value, the stronger the ecological service function of the internal landscape types in the ecological source area, which can better ensure the normal succession of the regional ecosystem, and the higher the ecological importance.

(5) Number of Animal and Plant Species. According to the scientific research report, the sum of the number of animal and plant species in an ecological source area is the number of animal and plant species in the ecological source area. The more the number of animal and plant species, the more complex the biological network constructed, the more stable the ecosystem of the ecological source area, and the stronger the function of promoting the stability of the regional ecosystem, which is more important for the regional ecosystem.

(6) Plaque Density Index. Patch density is the density of a certain type of landscape patches in a specific region, mainly reflected by the area, indicating the scale advantage of this type of landscape. The calculation formula is

$$D_i = \frac{n_i}{A}(10000)(100). \tag{5}$$

In the formula, D_i is the patch density of landscape type i , n_i is the total area of landscape type i, A is the area of the study area, and $(10000)(100)$ is the patch area/100 hm^2. In order to show the ecological importance of the ecological source, the patch density of No. i ecological source is the patch density in the absence of the ecological source.

The greater the patch density of the ecological source, the greater the advantage of the ecological source in the study area, the more obvious the leading role, and the corresponding more important.

(7) Fractal Dimension Index. Fractal dimension is an index to measure the complexity of landscape patches by using perimeter and area, which reflects the degree of landscape fragmentation. The higher the fractal dimension, the more complex and fragmented the distribution of landscape types, and the lower the integrity.

$$F_i = 2\ln\left(\frac{P}{4}\right)/\ln(A). \tag{6}$$

In the formula, F_i is the fractal dimension index of landscape type i, P is the patch perimeter of landscape type i, and A is the patch area of landscape type i. In order to show the ecological importance of the ecological source, the fractal dimension index of an ecological source is the fractal dimension in the absence of the ecological source.

The ecological service function of the ecological source area is mainly to play ecological service function, the structure of the ecological source area with large dimensions is more broken, it is difficult to form a more stable ecosystem structure, and the ecological service function is relatively poor, which is not conducive to the normal succession of the regional ecosystem. Therefore, the ecological source with a low dimension is more important.

(8) Polymerization Index. The aggregation degree reflects the aggregation degree of landscape types; the higher the aggregation degree of landscape types, the greater the probability of adjacent connection, and the higher the integrity of the ecosystem. The calculation formula is

$$\mathrm{J} = \left[\frac{G_{ij}}{\max \longrightarrow G_{ij}}\right](100). \tag{7}$$

In the formula, J is the aggregation index of a landscape type, G_{ij} is the number of similar adjacent patches of the corresponding landscape type, and $\max \longrightarrow G_{ij}$ is the maximum number of similar adjacent patches that may exist in the landscape type.

The aggregation degree of ecological headwaters reflects the aggregation degree of ecological headwaters in space, and the structure with high aggregation degree has a more frequent exchange of material, energy, and information and a higher degree of ecosystem integration, which is more important to the regional ecosystem.

(9) Cohesion Index. Cohesion reflects the centripetal force of landscape patches; the higher the cohesion, the smaller the ratio of side length to area of landscape patches, the higher the degree of inward agglomeration, the lower the impact of external interference on it, and the more stable the regional ecosystem. The calculation formula is

$$N = \left[1 - \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}P_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n}P_{ij}\sqrt{a_{ij}}}\right] \times \left[1 - \frac{1}{\sqrt{A}}\right]^{-1} \times 100. \tag{8}$$

In the formula, N is the cohesion index of the landscape type, P_{ij} is the perimeter of the ij patch, a_{ij} is the area of the ij patch, and A is the total number of grids. In order to show the ecological importance of the ecological source, the cohesion index of an ecological source is the cohesion in the absence of the ecological source.

The cohesion index of the ecological source reflects the shape characteristics of the ecological source structure. The larger the cohesion index is, the more circular the shape of the ecological source is, the higher the centripetal force is, and the smaller the probability of being exposed to the external ecosystem. The more stable the internal ecosystem is, the greater the influence on the ecosystem and the higher the ecological importance is.

(10) Connectivity Index. Connectivity reflects the degree of connection between landscape patches. Different types of landscapes in the ecosystem have different ecosystems, while the same types of ecosystems are connected together to form a larger scale, more frequent ecological flow, and more stable ecosystem. Therefore, the higher the degree of spatial

connection of the same type of landscape patches, the more stable the ecosystem. The calculation formula is

$$C_i = \left[\frac{\sum_{i=1}^{n} c_{ijk}}{n_i(n_i - 1)/2}\right] \times 100. \quad (9)$$

In the formula, C_i is the connectivity index of landscape type i, n is the total number of landscape patches, c_{ijk} is the number of connections between patches j and k related to patch i within the threshold distance, and n_i is the number of patches of landscape type i.

The study area has the same or similar landscape-type patches as the ecological source landscape; when the ecological source connects with other ecological sources through the patches, it effectively promotes the operation rate of ecological flow and promotes the stability of the ecosystem. Therefore, the higher the connectivity of the ecological source, the more stable the ecosystem, and the higher the ecological importance.

(11) Average Proximity Index. The average proximity reflects the distance between patches of the same type. The higher the average proximity is, the closer the patches are, the higher the frequency of ecological flow is, and the stronger the ecosystem function is. The calculation formula is

$$L_i = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} l_{ij}}{L}. \quad (10)$$

In the formula, L_i is the average proximity index of landscape type i, n is the total number of landscape patches, l_{ij} is the similar adjacent number of landscape patches i and j, and L is the total number of adjacent landscape patches.

The average proximity of ecological sources reflects the degree of separation between ecological sources. Because of the similar ecosystem composition and ecological service function, the closer the ecological source area is, the more overlapping the ecological service scope is, the stronger the ability to ensure regional ecological security, and the higher the ecological importance is.

3.3.2. Standardized Treatment. Principal component analysis (PCA) was used to analyze the above 11 indicators, the ecological importance of the ecological source area was scored, and the ecological importance of the ecological green heart was determined according to the scoring results. Centroid distance, the proportion of ecological service area, number of ecological source connections, average ecological service value, and number of animal and plant species are calculated according to the actual situation of each ecological source in the ecological network. The six landscape pattern indices were calculated based on a certain landscape type in the study area, and it was difficult to obtain the results by calculating a certain ecological source. Therefore, the landscape pattern indices were calculated based on the lack of a certain ecological source to reversely reflect the ecological importance of the ecological source. In order to ensure the consistency of data analysis, the measured indicators are standardized with the following formula:

$$Y_i = \frac{X_{\text{Max}} - X_i}{X_{\text{Max}}}, \quad (11)$$

$$Y_i = \frac{X_i - X_{\text{Min}}}{X_{\text{Min}}}, \quad (12)$$

In the formula, Y_i is the index standardized value of i ecological source, X_{Max} is the maximum value of the index, X_{Min} is the minimum value of the index, and X_i is the index value.

The smaller the patch density, mean proximity, connectivity, cohesion, aggregation, and centroid distance were, the more important the ecological source area was. The larger the proportion of ecological service area, fractal dimension, the number of ecological source connections, the average ecological service value, and the number of animal and plant species, the more important the ecological source is, and formula (11) is used for standardization.

3.4. Principal Component Analysis. Principal component analysis (PCA) is a multivariate statistical analysis method, which combines the characteristics of multiple variables into a small number of comprehensive variables that can reflect the characteristics of the original variables by using the idea of dimensionality reduction and linear transformation. This method eliminates the interference information on the basis of retaining the characteristics of the original variables, so as to grasp the main contradiction analysis problem. The company of the composite variable can be expressed as

$$\begin{cases} F_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \cdots + a_{1n}x_n \\ F_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \cdots + a_{2n}x_n \\ \vdots \\ F_m = a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \cdots + a_{mn}x_n. \end{cases} \quad (13)$$

In that formula, $a_{i1}^2 + a_{i2}^2 + a_{i3}^2 + \cdots a_{\text{in}}^2 = 1 (i = 1, 2, 3, \cdots, n)$, F_i is the i principal component.

In order to eliminate the subjective role in the evaluation process and scientifically analyze the ecological importance characteristics reflected by the quantitative indicators, the principal component analysis method was used to calculate the ecological importance score of each ecological source. The analysis steps are as follows:

(1) Standardizing the numerical value of the measured index and calculating a characteristic vector and a characteristic value

(2) Dividing the characteristic vector by the square root of the characteristic value to obtain a correlation coefficient matrix of the determination index

(3) Multiplying the normalized matrix by a correlation coefficient matrix to obtain a score coefficient matrix of the principal component

(4) Multiplying that score coefficient matrix by the proportion of the eigenvalue in the total eigenvalue to obtain a principal component score and adding the principal component score to obtain a final comprehensive score. The ecological source areas with higher scores have higher ecological importance

4. Results and Analysis

4.1. Construction of the Changsha-Zhuzhou-Xiangtan Ecological Network. The ecological network of the Changsha-Zhuzhou-Xiangtan region was constructed by using the cumulative cost distance model (Figure 2). There are 40 ecological sources in the Changsha-Zhuzhou-Xiangtan area (No. 1 is the ecological green heart). The total area of ecological sources is 241301.57 hectares, showing obvious spatial differentiation characteristics, 28 ecological sources in the north and 12 ecological sources in the south; the scale of ecological sources is relatively balanced. The ecological resistance was high in the center of the region and decreased to the north and south sides. The natural fracture method was used to identify five main high ecological resistance areas, and the largest high ecological resistance area was located in Liling City and Zhuzhou County, which was far away from the ecological source, reflecting that the land development and utilization needed to be adjusted. There are 59 ecological corridors with a total length of 1728.32 km. There are 18 ecological corridors in the south of the Changsha-Zhuzhou-Xiangtan area, accounting for 20.22% of the total length. There are 32 ecological corridors in the north of the Changsha-Zhuzhou-Xiangtan area, accounting for 48.43% of the total length. Seventy-nine ecological nodes were identified, of which 49 were located in the north of the Changsha-Zhuzhou-Xiangtan area and 30 were located in the south of the Changsha-Zhuzhou-Xiangtan area.

4.2. Evaluation of Ecological Importance Factors of Ecological Green Core

4.2.1. Correlation Analysis of Measurement Indexes. According to the principle of the selection of measurement indicators, the analysis results can truly and accurately reflect the ecological importance of ecological source sites only if the measurement indicators are independent of each other and have a certain correlation. The results are shown in Table 2. There were no significant correlations or highly significant correlations among the measurement indicators, and all of them had certain correlations, which were in accordance with the principle of selection of measurement indicators.

4.2.2. Single-Factor Evaluation of Measurement Indexes

(1) Spatial Location. From the centroid distance (Table 2), the ecological green center is only 34 km away from the centroid of the study area, ranking third in the linear arrangement from near to far from the ecological source to the study area, almost in the center of the study area. From the distribution of ecological sources, there are a large number of ecological sources around the ecological green core, which are close to the ecological green core, forming a pattern of the ecological green core as the core and spreading around. It can be seen that the ecological green core is in the core position of the ecological source group in the local region, and it is very close to the ecological centroid of the study area, which has a significant impact on the ecosystem of the study area.

(2) Scale Advantage. From the point of view of patch density (Figure 3), in the absence of the ecological green core, the patch density of the ecological source group is the lowest, indicating that the scale dominance of the ecological source group in the study area is sharply reduced, and the total area of the ecological source is obviously reduced, highlighting that the ecological green core plays an important role in maintaining the scale level of ecological green quantity in the Changsha-Zhuzhou-Xiangtan area. In terms of scale, the ecological green core is the largest ecological source in the study area, accounting for 21.88% of the total ecological source area. The number of surrounding ecological sources is large, but the scale is small. The ecological green core occupies a dominant position in the local regional ecosystem.

From the perspective of the proportion of ecological service areas (Table 2), the proportion of ecological service areas of the ecological green heart is the highest, reaching 14.57% of the study area, which is basically in the center of the study area and has an important impact on the ecosystem of the study area. The ecological service area of the ecological green center is 409543.41 hectares, covering 54.25% of the urban areas of Changsha, Zhuzhou, and Xiangtan, which has a great impact on the overall development of urban and rural areas in Changsha-Zhuzhou-Xiangtan and is the ecological basis for the integrated development of Changsha-Zhuzhou-Xiangtan urban agglomeration. The ecological service scope of the ecological green core covers 32436.56 hectares of the high ecological resistance area, involving three major high ecological resistance areas, of which the southern part of the ecological service scope intersects with the largest high ecological resistance area, highlighting the important ecological location, which is the basis for ensuring the ecological security of the Changsha-Zhuzhou-Xiangtan region.

(3) Spatial Layout. From the cohesion index (Figure 3), the lack of ecological green centers led to a sharp decrease in the cohesion of the ecological source group, indicating that the ecological green center has a strong centripetal, the proportion of the boundary line and area is lower than other ecological sources, the probability of external interference is low, and the ecosystem is relatively stable, which is conducive to enhancing the stability of the ecosystem in the Changsha-Zhuzhou-Xiangtan region.

From the fractal dimension index (Figure 3), in the absence the of ecological green core, the fractal dimension of the ecological source group is the highest, indicating that the degree of fragmentation of the ecological source group is significantly improved, reflecting that the existence of the ecological green core can effectively reduce the degree of fragmentation of ecological sources group. The ecological green core has the largest scale and is located in the center of the ecological source group in the Changsha-Zhuzhou-

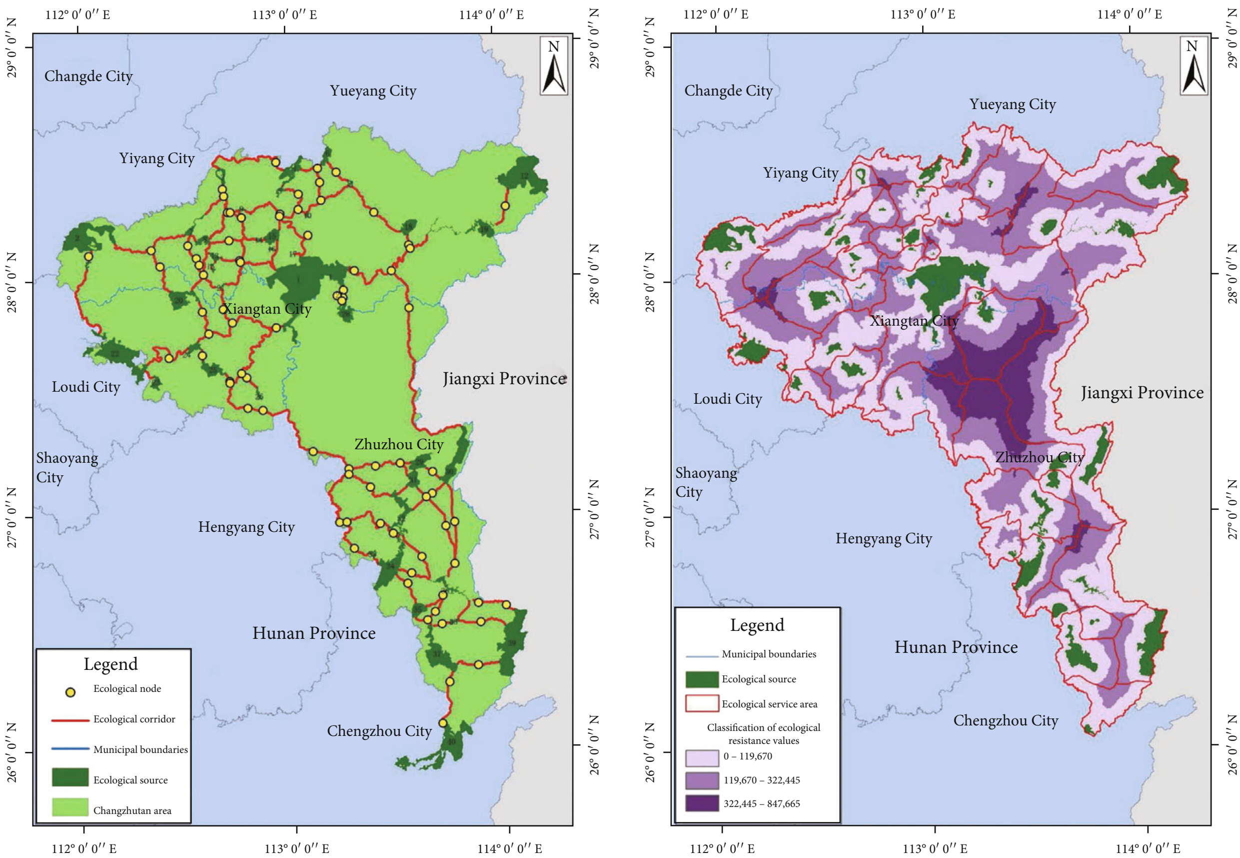

Figure 2: Ecological network and ecological resistance of the Changzhutan area.

Table 2: Correlation analysis of the measure indexes.

Indicator code	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	1.000										
X_2	-0.656	1.000									
X_3	-0.164	-0.263	1.000								
X_4	0.285	-0.566	0.399	1.000							
X_5	0.850	-0.635	0.134	0.494	1.000						
X_6	0.746	-0.645	0.155	0.444	0.855	1.000					
X_7	0.310	-0.197	-0.128	-0.087	0.171	0.140	1.000				
X_8	-0.250	0.139	-0.231	-0.165	-0.586	-0.440	0.129	1.000			
X_9	0.596	-0.541	0.228	0.690	0.714	0.710	-0.166	-0.276	1.000		
X_{10}	-0.211	0.217	0.088	0.283	-0.113	-0.167	0.207	0.108	0.113	1.000	
X_{11}	-0.206	-0.166	0.103	-0.148	-0.215	-0.209	0.149	0.275	-0.211	-0.115	1.000

Note: * indicates significant correlation at the 0.05 level, ** indicates significant correlation at the 0.01 level.

Xiangtan region, which effectively reduces the dispersion degree between the ecological sources and improves the integrity of the ecosystem.

From the perspective of the aggregation index (Figure 3), the lack of the ecological green core leads to a sharp decrease in the aggregation of ecological source groups, and the possibility of common edges between ecological landscape components is significantly reduced, reflecting that the ecological green core has an important function of enhancing the aggregation of ecological source groups and is a vital part of the ecological source group.

(4) Space Connection. In terms of the number of connected ecological sources (Table 2), the number of ecological green

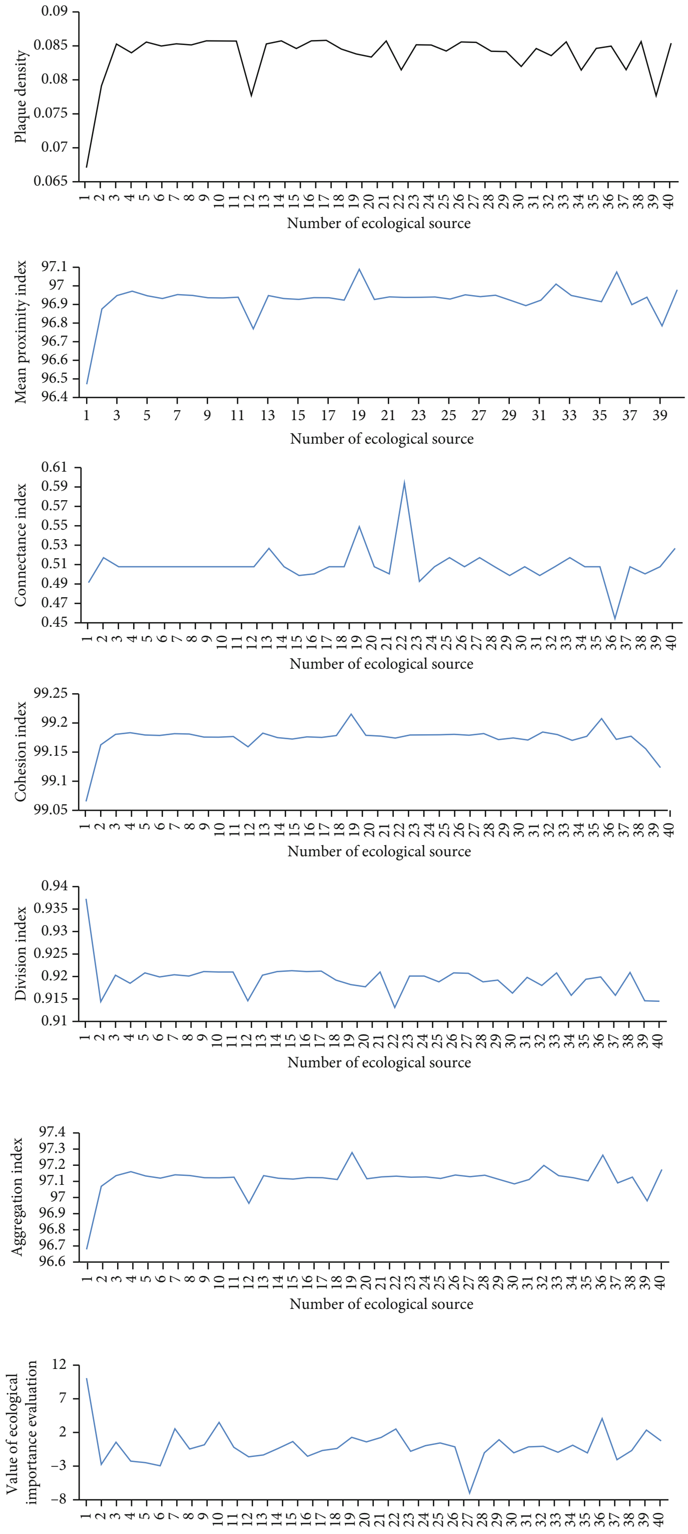

Figure 3: Landscape pattern index analysis and the ecological importance evaluation value of ecological sources.

centers connected with other ecological sources through ecological corridors reached 22, accounting for 55% of the total number of ecological sources, indicating that ecological green centers had a significant impact on the ecological processes of more than half of the ecological sources in the study area. From the spatial distribution of the ecological source, there is an obvious ecological source blank zone in the center of the study area, which divides the ecological source into two ecological source groups, north and south. Among them, the ecological green heart is located in the

Table 3: Statistical tables on the scale, ecological service area, core distance, connection number, ecological service value, and species of fauna and flora of ecological sources.

Number of ecological source	Scale		Ecological service areas		Core distance (km)	Connection number of source	Ecological service value (10000 Yuan/hm^2)	Species of fauna and flora
	Number	Proportion	Number	Proportion				
1	52788.65	21.88	409543.41	14.57	34.00	22	3.65	784
2	18936.09	7.85	129287.82	4.60	126.89	3	3.29	477
3	1615.57	0.67	14133.65	0.50	97.24	7	5.87	552
4	5271.09	2.18	43739.72	1.56	86.44	5	3.32	431
5	806.51	0.33	30284.85	1.08	78.84	2	3.19	469
6	2458.50	1.02	40535.74	1.44	91.49	3	2.55	395
7	1528.85	0.63	95417.79	3.39	87.25	6	7.31	687
8	2016.79	0.84	26747.61	0.95	79.49	5	3.41	449
9	333.46	0.14	20874.92	0.74	78.52	9	3.23	385
10	365.48	0.15	28251.85	1.01	64.58	7	7.16	538
11	402.01	0.17	80538.59	2.87	79.03	3	3.44	704
12	22900.73	9.49	117801.83	4.19	122.40	1	3.11	3068
13	1611.44	0.67	28171.91	1.00	69.80	7	2.79	375
14	345.16	0.14	18082.77	0.64	62.24	6	3.12	437
15	3510.76	1.45	13716.39	0.49	60.36	6	4.53	1158
16	333.68	0.14	17271.38	0.61	55.39	2	2.60	976
17	120.07	0.05	4635.53	0.16	48.85	5	2.94	3941
18	3697.90	1.53	80597.47	2.87	68.56	4	3.42	522
19	5749.26	2.38	152203.03	5.42	90.03	4	5.29	1046
20	7004.13	2.90	86627.43	3.08	74.99	7	2.86	409
21	385.94	0.16	27050.67	0.96	60.10	6	4.68	471
22	12311.11	5.10	90228.14	3.21	100.20	3	7.01	945
23	1968.99	0.82	27314.07	0.97	84.02	1	3.11	1573
24	2040.74	0.85	63083.04	2.24	64.79	6	2.82	1387
25	4534.80	1.88	50089.53	1.78	56.92	7	2.52	1161
26	766.39	0.32	109896.19	3.91	39.96	6	3.35	1046
27	942.37	0.39	6831.64	0.24	26.21	2	2.31	413
28	4621.62	1.92	119165.67	4.24	19.03	2	3.06	693
29	4759.41	1.97	138397.01	4.92	66.84	5	4.48	946
30	10925.10	4.53	197503.65	7.03	77.36	5	3.21	514
31	3498.19	1.45	17099.43	0.61	71.90	6	3.18	473
32	6442.18	2.67	111491.45	3.97	82.63	7	3.15	516
33	748.47	0.31	33755.72	1.20	97.47	4	3.09	437
34	12398.98	5.14	52493.78	1.87	105.82	4	3.28	948
35	3470.49	1.44	25840.62	0.92	128.47	3	3.09	418
36	2495.09	1.03	98767.30	3.51	123.09	8	6.73	573
37	12271.61	5.09	66878.00	2.38	151.34	5	3.16	474
38	631.44	0.26	23716.95	0.84	139.76	3	3.49	486
39	23015.56	9.54	64735.04	2.30	161.49	3	3.34	2211
40	1276.96	0.53	47753.16	1.70	194.26	1	5.65	2499
Total	241301.57	100	2810554.77	100.00	3408.05	201	3.95	——

south of the center of the northern ecological source group, with a large number of surrounding ecological sources, which are connected with 22 other ecological sources through a 788.14 km ecological corridor (accounting for 45.60% of the total length of the ecological corridor), of which 2 ecological corridors connect the north-south ecological source group, reflecting that the ecological green heart is the key to the regional ecosystem. It shoulders the important ecological function of connecting the north-south ecosystem of the Changsha-Zhuzhou-Xiangtan area.

Table 4: Statistical table of the total variance.

Component	Initial eigenvalue Add up	% of variance	Cumulative%	Extract sum of squares load Add up	% of variance	Cumulative%
1	4.437	40.340	40.340	4.437	40.340	40.340
2	1.525	13.866	54.206	1.525	13.866	54.206
3	1.422	12.930	67.136	1.422	12.930	67.136
4	1.104	10.034	77.170	1.104	10.034	77.170
5	0.881	8.005	85.174			
6	0.721	6.558	91.732			
7	0.334	3.036	94.768			
8	0.226	2.053	96.821			
9	0.194	1.761	98.582			
10	0.132	1.199	99.782			
11	0.024	.218	100.000			

Among the ecological nodes, 34 are located in the ecological corridor connecting the ecological green heart with other ecological sources, accounting for 43.04% of the total number of ecological nodes. From the distribution of ecological corridors and ecological nodes, it can be seen that the ecological green core is very important to ensure the connectivity and stability of the regional ecosystem.

From the average proximity index (Figure 3), in the absence the of ecological green core, the average proximity of the ecological source group reaches the lowest value, indicating that the existence of the ecological green core greatly reduces the average distance between ecological sources, which is conducive to the formation of a more holistic ecological source structure.

From the point of view of the connectivity index (Figure 3), the connectivity of ecological source groups is the lowest in the absence of the No. 36 ecological source, followed by the absence of the ecological green heart, indicating that the existence of the ecological green heart significantly increases the number of spatial links between ecological sources, effectively forms more high-speed channels for the operation of ecological flows, and promotes the development of ecological sources. It highlights the important function of promoting the exchange of ecological materials, energy, and information in the ecosystem. In addition, the No. 36 ecological source is located in the center of the southern ecological source group, which is the core of the southern ecological source connections and has the highest connectivity.

(5) Ecological Composition. In terms of ecological service value (Table 3), the ecological green core ranked 11th in the ecological source group from high to low, which did not reach the average ecological service value of the ecological source group, indicating that the landscape type composition structure of the ecological source area had a general ability to guarantee the normal ecological process and had a general role in promoting the ecosystem of the study area, so it was necessary to adjust and optimize the internal composition.

Table 5: Component matrix.

Measurement index	Component 1	2	3	4
X_1	0.821	-0.397	0.036	0.112
X_2	-0.778	0.159	-0.418	0.214
X_3	0.263	0.603	0.360	-0.200
X_4	0.653	0.419	0.357	0.102
X_5	0.945	-0.115	-0.179	0.027
X_6	0.896	-0.151	-0.154	0.013
X_7	0.115	-0.737	0.174	0.239
X_8	-0.474	-0.189	0.563	0.320
X_9	0.836	0.290	0.001	0.173
X_{10}	-0.035	0.285	0.065	0.875
X_{11}	-0.166	-0.150	0.763	-0.199

In terms of the number of animal and plant species (Table 3), the ecological source group of the ecological green heart ranked 15th from high to low, which was at a lower level compared with the ecological source group with a large number of animal and plant species and had low value in wildlife protection. This may be related to the fact that the ecological green core is close to human society and there are many interference factors, and at the same time, it reflects that the internal composition of the ecological green core needs to be adjusted and optimized urgently.

4.3. Evaluation of Ecological Importance of Ecological Green Core. Principal component analysis (PCA) was used to analyze the measured indexes, and the principal components with eigenvalues greater than 1 were selected with the cumulative variance contribution rate greater than 75% as the constraint standard. The results are shown in Tables 4 and 5.

Four principal components were selected, and the cumulative variance contribution rate reached 77.17%, which basically reflected the change characteristics of the measured

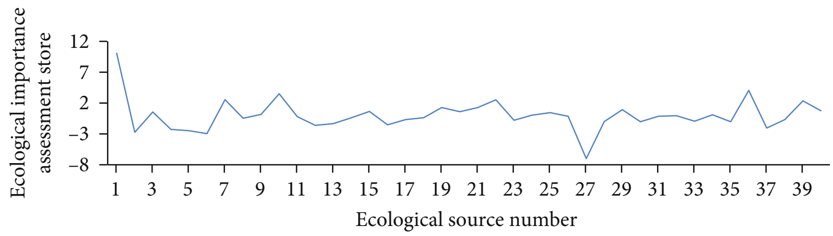

Figure 4: The ecological importance evaluation value of ecological sources.

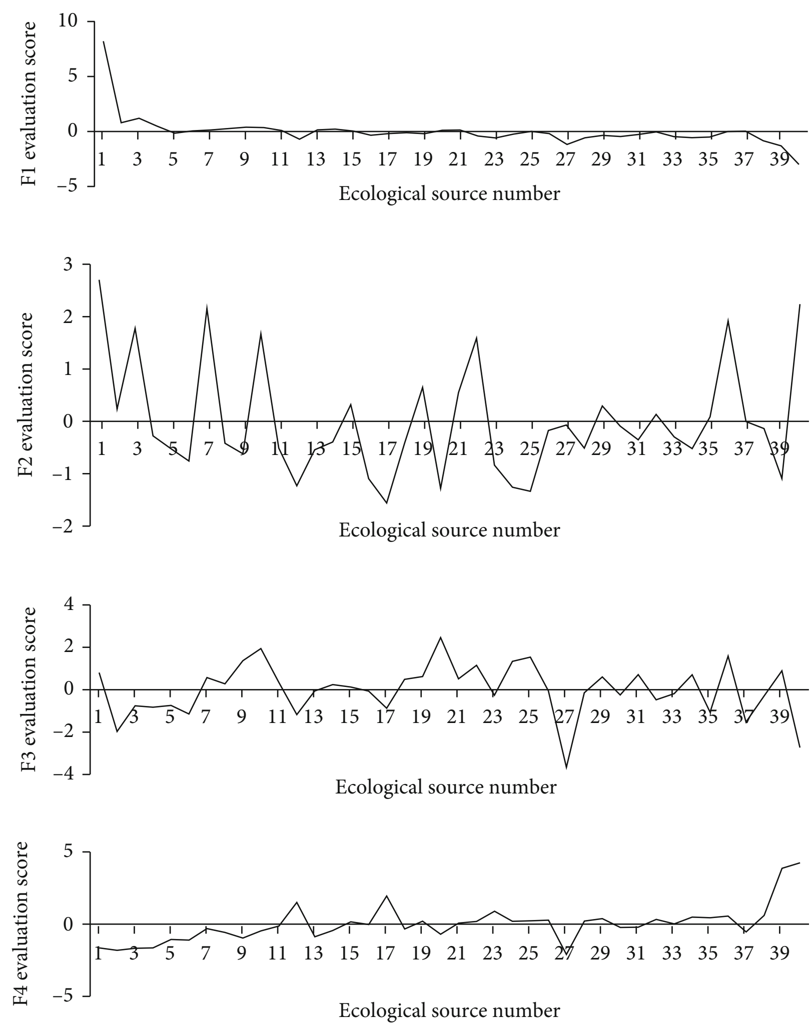

Figure 5: Ecological importance principal component evaluation value of ecological sources.

indicators. Patch density, average proximity, cohesion, fractal dimension, and aggregation degree were the most important indexes of principal component F1, and principal component 1 could be summed up as spatial structure index. Connectivity, centroid distance, and the number of connected ecological sources are the most important indexes in principal component F2, and principal component 2 can be summed up as the spatial connection index. The principal component F3 has a larger load on the determination indicators of the proportion of ecological service areas and the number of animal and plant species, which are the indicators to characterize the ecological service function of ecological sources. The largest load on principal component F4 is the average ecological service value, which is the index to characterize the ecological composition of the ecological source. According to the principal component analysis, the load

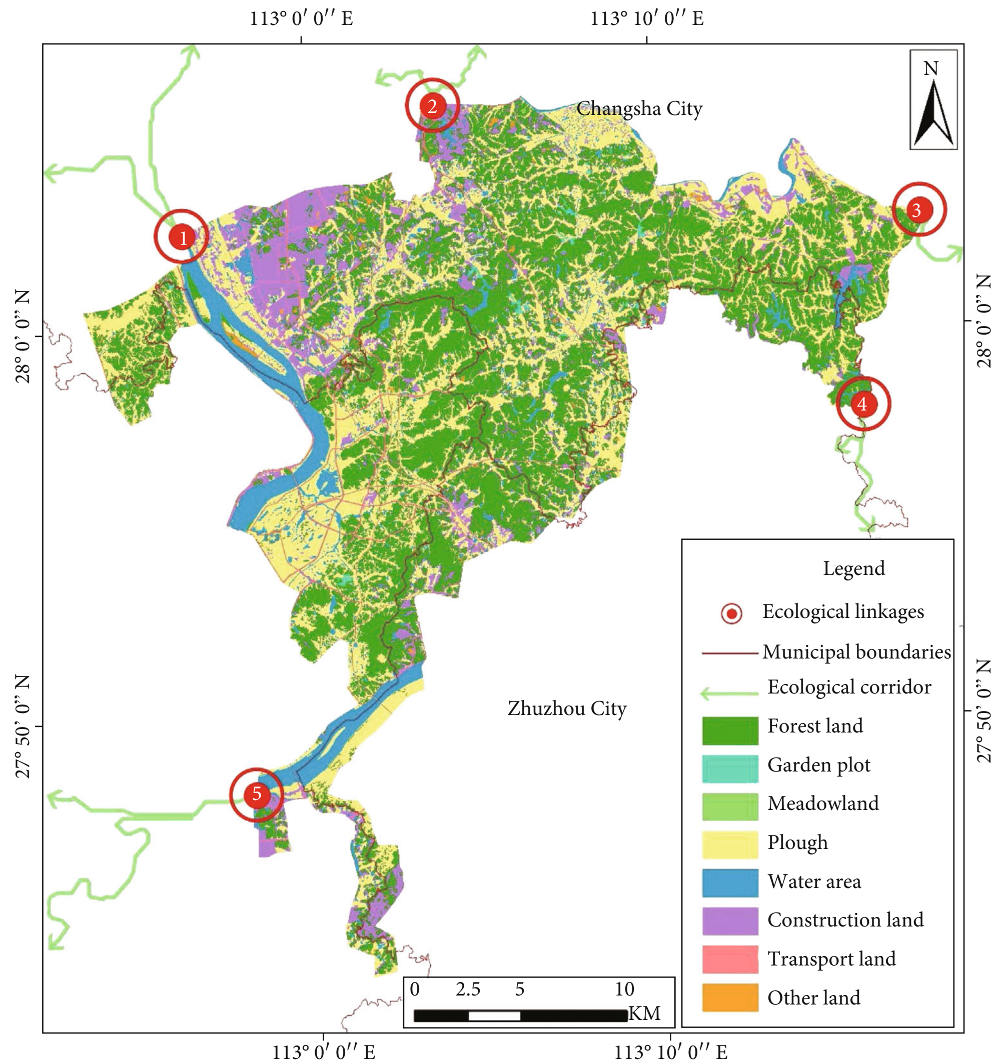

Figure 6: Important ecological connection point and land use status of the Changzhutan ecological green heart.

matrix of ecological importance evaluation of ecological headwaters in the Changsha-Zhuzhou-Xiangtan region can be expressed as follows:

$$\begin{aligned}
F_1 &= 0.390X_1 - 0.369X_2 + 0.125X_3 + 0.310X_4 + 0.449X_5 + 0.425X_6 + 0.055X_7 - 0.225X_8 + 0.001X_9 - 0.017X_{10} - 0.079X_{11},\\
F_2 &= -0.321X_1 + 0.129X_2 + 0.488X_3 + 0.339X_4 - 0.093X_5 - 0.122X_6 - 0.597X_7 - 0.153X_8 + 0.397X_9 + 0.231X_{10} - 0.121X_{11},\\
F_3 &= 0.030X_1 - 0.351X_2 + 0.302X_3 + 0.299X_4 - 0.150X_5 - 0.129X_6 + 0.146X_7 + 0.472X_8 + 0.235X_9 + 0.055X_{10} + 0.640X_{11},\\
F_4 &= 0.107X_1 + 0.204X_2 - 0.190X_3 + 0.097X_4 + 0.026X_5 + 0.012X_6 + 0.227X_7 + 0.305X_8 + 0.165X_9 + 0.833X_{10} - 0.189X_{11}.
\end{aligned} \tag{14}$$

According to the load matrix, the ecological importance score of each ecological source area is calculated (Figure 4). The highest score of ecological importance was the ecological green core, with a score of 10.07, which was 2.48 times higher than that of the No. 36 ecological source (4.0561) and much higher than that of other ecological sources. It indicated that the ecological green core was far more important than other ecological sources in the study area.

From the four principal component scores (Figure 5), we can see that the ecological function of the ecological green heart is mainly manifested in the principal component 1, that is, the spatial structure function. The score of spatial structure index of the ecological green core is far higher than that of other ecological source areas, which is the most important ecological function of the ecological source area in ecological source area group, that is, to improve the spatial structure of the ecological source area group and to form a more holistic and stable ecosystem. The secondary function of the ecological green core was the spatial connection function, which was significantly higher than other ecological sources. It indicated that the existence of the ecological green core significantly enhanced the spatial connection function of the ecological source group. From the evaluation results of F2, it can be seen that there are two levels of differentiation in the spatial connection of ecological sources. The ecological source near the center of the ecological source group has a higher spatial connection function, while the ecological source at the edge of the study area has a relatively low ecological connection function. The ecological function of the ecological green core is the ecological service function again, and the ecological service function of the ecological green core has no advantage in the whole ecological source group, because the number of animal and plant species in the ecological source group is too small. The ecological function of the ecological green core is ecological composition, and the average ecological service value of the ecological green core is not high, mainly due to the existence of a large proportion of construction land and cultivated land. This also reflects that the ecological green heart urgently needs to carry out landscape pattern optimization and improve its ecological service function.

5. Discussion and Conclusion

5.1. Discussion. The study innovatively constructed an ecological importance evaluation system for ecological source sites from five aspects of spatial location, scale advantage, spatial layout, spatial connection, and ecological composition. According to the evaluation results, the importance of ecological composition of the ecological green heart is only medium, but the importance of other four spatial structures is very prominent, reflecting that the importance of the ecological green heart is mainly manifested in spatial structure, and the key point of ecological construction is to enhance the connection function between ecological green heart and other ecological sources from the perspective of spatial structure. And that stability of the ecological green core is improved, and the ecological composition of the ecological green core is in urgent need of optimization. From the current landscape pattern of the ecological green center (Figure 6), the interlocking of arable land and woodland increases the resistance of ecological flow operation, while the distribution of arable land on both sides of Xiangjiang River blocks the spatial connection of ecological components. At present, arable land accounts for 32.28% of the total area of the ecological green center, and agricultural production interferes strongly, which needs to strengthen spatial control, limit the intensity of agricultural production, and manage agricultural pollution. At the same time, the built-up areas of cities and towns in Changzhutan have penetrated into the interior of the ecological green center, among which the northern part of the ecological green center is particularly prominent. How to deal with the relationship between urban development and ecological protection and improve the development pattern of urban space and ecological space is the key to protect the ecological green center. Therefore, the ecological construction measures inside the ecological green center are as follows: first, to build an ecological network and strengthen the protection of key ecological spaces inside the ecological green center; second, to scientifically delineate ecological red lines, implement ecological restoration measures, expand the scale of ecological landscapes, and do a good job of spatial control to ensure ecological security; third, to limit urban disorderly expansion, explore benign coupling mechanisms, and promote coordinated economic and social development; and fourth, to manage disturbing factors, improve forest, wetland quality and regional management level, and promote ecological functions.

According to its position in the ecological network, there are five important ecological connections between the ecological green heart and the ecological corridor, which are the key channels connecting the ecological green center with the external ecosystem and also the connection points for the ecological green core to play an important ecological core hub function, so the ecological significance is great. According to the landscape types of ecological connection points, No. 1, No. 4, and No.5 are located in water areas, and the key points of ecological construction are to protect wetland resources, give full play to wetland biodiversity function, and strengthen water pollution prevention and control; No. 2 is located in the urban area of Changsha City, located in the construction land; the focus of ecological construction is to strengthen ecological protection and ecological restoration, keep the ecological red line, limit the city to continue to expand and infiltrate the ecological green heart, while strengthening space control, and reduce the impact of human activities on the ecological green heart; No. 3 is located in economic forest, which needs to deal with the relationship between management and protection, enrich forest structure, construct ecological shelter belt, and reduce human disturbance.

Using the spatial characteristics of ecological networks, the study evaluated the ecological importance of ecological green centers in the Changzhutan urban agglomeration and achieved the purpose of quantifying the ecological functions of ecological source sites from a macroscopic perspective. Unlike the traditional ecological importance studies, which target the microecological functions of geographical units such as administrative districts, watersheds, and forests, and the ecological importance studies [25–27], which are based on factors such as resource endowment and development status characteristics, this study attaches more importance to exploring the macroecological functions of ecological source areas from the perspective of the overall spatial structure of regional ecosystems, which makes up for the ecological function evaluation the lack of macro connotation, which is conducive to strengthening ecological construction from the perspective of enhancing the overall stability of regional ecosystems [28, 29]. The results of the comprehensive measurement index evaluation show that different ecological source sites have different functions and roles in the regional ecosystem, and their ecological importance varies; not the larger the scale and the richer the biodiversity, the more important the ecological source site is, but the ecological importance of the ecological source site is also influenced by spatial location, spatial connectivity, surrounding environment, and other factors. This reflects that the method of using ecological networks to explore ecological functions of ecological source sites in reverse is scientific and feasible, which can effectively analyze different ecological functions of ecological source sites from the perspective of spatial structure and provide a reference for clarifying the focus of the ecological source site construction. Of course, due to the limitations of the research purpose and method, the study mainly analyzed the ecological functions of ecological source sites from the perspective of macroscopic spatial structure, only considered the ecological functions of microscopic aspects in terms of ecological service value and biodiversity, and the evaluation results inevitably focused on the ecological functions of ecological source sites in terms of spatial structure to the microecological functions of ecological source sites, combined with macroecological function evaluation, and further improved the ecological importance evaluation system. Meanwhile, the construction of the ecological network is the premise of this study to evaluate the ecological functions of ecological source sites and their ecological importance. This method is based on the idea of ecological planning and inverse deduction, it is the first time to be applied in ecological function analysis and ecological importance evaluation of ecological source sites, and there is a lack of existing studies as comparative cases to reflect the evaluation accuracy of this method, but from the evaluation results, this method has good applicability and is inspiring for ecological source sites. However, from the evaluation results, the method has good applicability and is inspiring for the special research and function evaluation of ecological source sites.

5.2. Conclusions. The study constructs an ecological importance evaluation system for ecological source sites, innovatively evaluates the ecological importance of ecological green centers based on the spatial characteristics of ecological networks in Changzhutan urban agglomeration, clarifies the ecological functions and important roles of ecological green centers in the ecosystem of Changzhutan urban agglomeration, and can propose scientific references for the protection and construction of ecological green centers.

(1) The evaluation system was constructed by selecting 11 measurement indexes from five aspects: spatial location, scale advantage, spatial layout, spatial connection, and ecological composition, and the ecological functions of ecological source sites were regrouped and classified by using principal component analysis to complete the ecological importance analysis and evaluation. The results can effectively reflect the ecological function of ecological source and highlight the ecological importance. The ecological green center is the ecological source site with the highest ecological importance in the Changzhutan city cluster, and its main ecological function is to strengthen the spatial structure, followed by the spatial connection function, and the ecological service function is relatively low. At the same time, the analysis results of the measured indexes show that the ecological functions and importance of each ecological source site in the regional ecosystem are different, reflecting that the method of inverse deduction of ecological functions of ecological source sites based on ecological networks is feasible and effective, providing an idea to explore the multiple ecological functions of ecological source sites from the combination of macro and micro perspectives

(2) The ecological function of the ecological green heart is very significant. The ecological green heart is the largest ecological source land in Changzhutan urban agglomeration, which directly affects 55% of the ecological source land in the whole area through the ecological corridor, is the core hub connecting the north and south ecosystems of Changzhutan urban agglomeration, and is in a dominant position in the regional ecosystem, which is very important to guarantee the regional ecological security and maintain the stability of the ecosystem and is also the basis for promoting the coordinated development of the built-up areas of the towns in Changzhutan cities. In the absence of the ecological green heart, the patch density, average proximity, cohesion, and aggregation of the ecological source land structure of the Changzhutan urban cluster fall to the lowest, the connectivity falls to the second lowest, and the subdimension reaches the highest, indicating that ecological green heart plays an important role in maintaining the ecological green volume of the Changzhutan urban cluster, enhancing the overall ecosystem connectivity and reducing the fragmentation. However, the ecological service value and the number of plant and animal species in the ecological green center are at the average level, and its internal ecological composition is not conducive to the performance of ecological service functions, so it is necessary to optimize the landscape pattern and improve the quality of the ecological landscape pattern inside the ecological green center

(3) There are five important ecological connection points between the ecological green core and the ecological corridor in the ecological network of the Changzhutan city cluster, including three water ecological connection points, one urban construction land ecological connection point, and one garden ecological connection point, which need to take different measures to strengthen ecological protection and construction. The cultivated land inside the ecological green core has obvious barrier effect on the ecological landscape. We should pay attention to the optimization of the landscape pattern inside the ecological green core, construct the ecological network, increase the green quantity, improve the ecological service function, implement the spatial control, and limit the disorderly expansion of the city

Data Availability

The raw data supporting the conclusions of this article are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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