Research Article

Construction of Ecological Network of Yangtze Huaihe River Diversion Project (Anhui) Based on Landscape Connectivity Index

Jing Jin,1 Wenqing Ding,1 Zhengyu Zhu,1 Jiaqi Zhou,1 Guangzhi Shi,1 Youhua Ma,2 and Zhenhua Chen3

1College of Forestry and Landscape Architecture, Anhui Agricultural University, Hefei, Anhui 230036, China
2College of Resources and Environment, Anhui Agricultural University, Hefei, Anhui 230036, China
3School of Urban Construction, Anhui Xinhua University, Hefei, Anhui 230088, China

Correspondence should be addressed to Wenqing Ding; dwq@ahau.edu.cn

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The interbasin water transfer project has realized the optimal allocation of water resources, improved economic benefits, improved people’s life and welfare, and had an impact on the ecology. Taking Anhui Jianghuai water transfer project as an example, this study uses morphological spatial pattern analysis (MSPA) to identify the core area, selects the patches in the core area, identifies the source according to the patch importance index, constructs the basic resistance surface according to the resistance factor, modifies the basic resistance surface by using the landscape connectivity index, and constructs the ecological corridor by combining the minimum cumulative resistance (MCR) model and the loop model (curve) to build the ecological network of the completed Huaihe River Water Transfer Project (Anhui). The results show that there are 83 sources, 197 potential ecological corridors, and 80 ecological nodes in the ecological network of Anhui Jianghuai project. Ecological network optimization strategies and protection suggestions are put forward for ecological sources, ecological corridors, and ecological nodes, respectively, so as to provide scientific reference and basis for the ecological environment protection and high-quality development of Anhui Jianghuai water transfer project.

1. Introduction

The interbasin water transfer project from the Yangtze River to the Huaihe River has brought people’s well-being to the society, and along with a series of problems to be solved urgently, the area of river bend straightening, channel hardening, and engineering facilities hardening has greatly increased [1, 2] river dredging and expansion, and the water surface area has increased. The area of wetlands and beaches decreased sharply, resulting in the change of hydrological law [3]. The water transfer project occupies a lot of ecological space such as forest land and grassland, blocks the connection of habitat patches, and is easy to cause patch “island.” In addition, water diversion projects and port development also occupy urban space, forcing residents along the line to migrate. Due to the centralized resettlement of population, the agglomeration effect of cities and towns is increased, and the possibility of occupying ecological land and production land is also increased [4]. These problems directly lead to the change of land use types, resulting in serious environmental fragmentation in some areas, serious shrinkage of habitat patch boundary, reduced connectivity [5], interruption of ecological corridor connection, and the risk of fracture of regional ecological network [6]. It greatly reduces the operation and regulation ability of the ecosystem, puzzles biological migration, directly affects the regional ecosystem, and threatens the regional sustainable development [7].

Since 1900, the academic research on ecological network has gradually increased. With the deepening of research level and technology, the construction of ecological network can effectively improve the regional environment and strengthen the connectivity of regional landscape [8]. Ecological network can better connect broken habitats and provide
channels for species migration between patches [9]. The key to the rationality of constructing ecological network depends on the identification of ecological sources and the selection of ecological corridors. There are two main methods for identifying ecological sources: the first is the direct method, that is, directly taking green patches such as nature reserves, forests, and parks with high ecological service value as ecological sources, which is more subjective and ignores the connectivity role of patches in the landscape [10]. The second is the comprehensive method, that is, the comprehensive analysis methods such as particle size back extrapolation, principal component analysis [11], landscape pattern analysis [12, 13], and the ecological network research method of invest model [14] are used for research. In recent years, morphological spatial pattern analysis (MSPA) has been widely used to identify ecological sources in ecological networks [15]. Compared with the first two methods, MSPA method is an image solution to measure, recognize, and segment the spatial pattern of regional land use data grid image. MSPA can accurately distinguish the type and structure of landscape and quantitatively identify the ecological source [16]. The identification methods of ecological sources vary with different research purposes [17, 18]. Weijie et al. used the MSPA model to obtain patches in the core area. The overall integral index of connectivity (IIC), probability of connectivity index (PC), and patch importance index (dpc) evaluate the landscape connectivity of the study area and extract patches with high connectivity. In the landscape connectivity analysis, the setting of distance threshold has a great impact on the analysis results. The distance threshold obtained only based on relevant literature may lead to the analysis results that cannot truly reflect the landscape continuity of the study area, but few people have made further research on the connectivity index. Jérôme Dupras used the ecological connectivity index (ECI) and land matrix to obtain the adaptation cost distance of the ecological function area of each landscape type. Based on the different resistance values of the same landscape type, Qi and Song use the connectivity index to correct the resistance surface. The correction of resistance surface is more scientific for the identification of potential corridors and the construction of ecological network. Ecological corridor is the channel of regional material and energy flow. The minimum consumption distance model (MCR), the minimum cost path model linkage mapper, and the land use corridor model (NFC) all use the minimum cost method to identify the corridor connecting the two landscapes. The above methods make the in-depth study of regional ecological network possible. Therefore, the distance threshold gradient method is used to determine the optimal distance threshold. Through the comparison of the results of multigradient parameters, this method can provide a supplement for the construction of regional ecological network more objectively. However, few people verify the effectiveness of such models to distinguish corridors through experience or theory. Unverified or connectivity-based models can lead to inefficient management decisions. Based on the connectivity index of ecological network, exploring the similarities and differences of constructing ecological network based on minimum consumption resistance model and circuit theory, and integrating the two models to optimize the network have far-reaching significance for regional environmental protection [19].

The Huaihe River Basin and the Yangtze River Basin have important ecosystem services such as water conservation, biodiversity maintenance, and climate regulation. Human activities have broken the regional habitat and reduced the landscape connectivity. Therefore, this study uses the MSPA model and connectivity index to identify and extract the source, modifies the resistance surface with connectivity index, integrates MCR model and circuit model to identify the potential ecological corridors, completes the construction and evaluation of ecological network, discusses the optimal construction method of ecological network, and points out the direction for the ecological network planning of the Yangtze River to Huaihe River Project (Anhui). It is expected to provide scientific basis for the optimization of ecological network and ecological environment protection of regional water transfer projects [20–22].

2. Material and Methods

2.1. Study Area and Data Sources. The Yangtze River to Huaihe River Diversion Project (Anhui) (30°53′–34°68′N, 114°51′–118°61’E) has undulating terrain. The Yangtze River and Huaihe River take the Yangtze Huaihe River watershed as the ridge and incline to the southeast and north sides, and there are low-lying polder areas along the river. There are undulating hills between the Yangtze and Huaihe rivers (Figure 1). To the north of the Huaihe River is the Huaibei plain, which gradually rises to the northwest. The landscape of the area involved in the project can be divided into three geomorphic units: alluvial plain along the river, Jianghuai wavy plain, and Huaibei alluvial plain.

The data mainly involved in this study include 30 meter precision data of land use in 2020, vegetation coverage data, road data and river network data in 2018, and DEM data. The data sources are listed in Table 1.

2.2. Determination of Ecological Source

2.2.1. Identification of Ecological Sources Based on MSPA. MSPA is a method of quantitative identification of ecological sources. It mainly identifies and classifies ecological sources through image analysis. First, the land use types in the study area are divided into forest land, grassland, wetland, water body, construction land, cultivated land, and bare land. The four landscape types such as forest land, grassland, wetland, and water body are set as the foreground and the others as the background and are converted into TIFF format and imported into Guido stool box software. Through MSPA analysis, seven nonoverlapping landscape types are obtained (Table 2): core, islet, perforation, edge, bridge, loop, and branch. The landscape type of the core area is based on the island biogeography theory proposed by Mac Arthur and Wilson to further identify the ecological source.
2.2.2. Distance Threshold Setting and Landscape Connectivity Index. Using Conefor26 software, the number of links (NL), number of components (NC), equivalent connectivity (EC), integral index of connectivity (IIC), probability of connectivity (PC), and patch importance (DI) are calculated. Through the distance threshold gradient method, the changes of relevant index values under 15 groups of distance thresholds of 50 m, 100 m, 200 m, 400 m, 600 m, 800 m, 1000 m, 1200 m, 1500 m, 2000 m, 2500 m, 3000 m, 4000 m, 5000 m, and 8000 m are compared to determine the best distance threshold. The landscape connectivity index of the core area extracted based on MSPA is calculated, the source is determined, and the resistance surface is corrected.
2.3. Integrated MCR Model and Circuit Model to Identify Corridor

2.3.1. Construction Foundation Surface Resistance. Species migration and energy exchange between sources need to overcome certain resistance, and the resistance surface is constructed to quantify the degree of obstruction of material and energy flow. In terms of the comprehensiveness and availability of data in the study area, in the relevant research of He, Hu, and Zhai, nine factors were selected, including land use type, MSPA landscape type, altitude, slope, vegetation coverage NDVI, distance to water, distance to railway, distance to highway, and distance to building land, and the hierarchical allocation of each factor was determined. Among the land use types, wetland types and water types are combined into water bodies, which is convenient for calculation. Based on the analytic hierarchy process, the hierarchical structure model is constructed, and the consistency test of the judgment matrix is passed to determine the weight of each factor (Table 3). Based on the superposition analysis of 9 single factor resistance surfaces, the basic resistance surface is obtained.

2.3.2. Resistance Surface Correction. Due to the location of the landscape, human interference, and other reasons, the same landscape type sometimes does not have the same ecological resistance value. Therefore, landscape connectivity is used to modify the resistance surface. According to the equispaced classification, the connectivity index is divided into five levels: low, relatively low, medium, relatively high, and high. Based on the ArcGIS platform, Shuangwang revised the ecological resistance surface in 2021. The formula is as follows:

\[ R_i = R \times \frac{LC_{ave}}{LC_i} \]  

(2)

where \( R_i \) is the ecological resistance value of grid \( i \) modified by landscape connectivity, \( LC_i \) is the landscape connectivity of grid \( i \), \( LC_{ave} \) is the average landscape connectivity of grid \( i \) of the same landscape type, and \( R \) is the basic resistance value of grid \( i \) based on the corresponding landscape type.

2.3.3. Integrated MCR and Circuit Model to Identify Corridor. The minimum cumulative resistance model is used to obtain the minimum cumulative resistance surface of ecological source expansion around. The formula is as follows:

\[ MCR = f_{\min} \sum_{j=1}^{in} (D_{ij} \times R_j) \]  

(3)

where MCR is the minimum cumulative resistance value, \( f \) is the positive correlation between minimum cumulative resistance and sink, \( min \) is the evaluated plaque takes the minimum cumulative resistance for different sources, \( \sum \) is the sum of the resistance and distance consumed between grid \( i \) and source \( j \), \( D_{ij} \) is the distance between source \( i \) and source \( j \), and \( R_j \) is the resistance coefficient of the spatial grid \( j \) to the sink.

Based on ArcGIS tools, the path of an ecological source and its remaining sources is analyzed in turn to obtain the unit ecological corridor. Finally, all ecological corridors are combined and redundant to obtain the potential ecological corridor between ecological sources.

McRae first proposed the isolation by resistance (IBR) model to predict the genetic research of species in complex landscape and gradually developed to the circuit theory to predict the migration and diffusion process of biological population. Circuit theory refers to simulating the migration

| Table 2: Landscape types and ecological meanings of MSPA. |
|---------------------------------|---------------------------------|
| Landscape types                | Ecological implications         |
| Core                            | The larger habitat patch in the prospect can provide a larger habitat for species, which is of great significance for biodiversity protection and is the ecological source in the ecological network. |
| Islet                           | For isolated and broken small patches that are not connected to each other, the connectivity between patches is relatively low, and the possibility of internal material and energy exchange and transmission is relatively small. |
| Perforation                     | The transition area between the core and background patches, that is, the edge of the internal patch. |
| Edge                            | It is the transition area between the core and the background. |
| Bridge                          | The narrow and long area connecting the core is of great significance for biological migration and landscape connection. |
| Loop                            | The corridor connecting the same core area is a shortcut for species migration in the same core area. |
| Branch                          | Only one end is connected to the area of Yao ring or hole at the edge of Yao bridge. |

\[ IHC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} a_i a_j / I + n l_{ij}}{A_L^2} \]

\[ PC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} a_i a_j p_{ij}^j}{A_L^2} \]

\[ dl (dPC) = \frac{I - I'}{I} \times 100 \]

where \( n \) is the number of patches; \( a_i \) and \( a_j \) are the areas of plaque \( i \) and \( j \) respectively; \( a_i \) is the total landscape area; \( p_{ij}^j \) is the maximum probability NL of species dispersion in patches \( i \) and \( j \); \( n l_{ij} \) is the minimum number of cost paths between patches \( i \) and \( j \). \( dl \) indicates the importance of removing elements; \( I \) is the connectivity calculation result; \( I' \) represents the connectivity calculation result after removing a certain element. The greater the \( dl \) value, the greater the importance between elements. Among these indexes, except NC, other indexes are all. The larger the value, the higher the landscape connectivity.
and diffusion process of individual species or genes in the landscape by using the random walk characteristics of electrons in the circuit and using the current intensity between sources to reflect the relative importance of ecological patches and corridors, so as to predict the law of species diffusion and migration and identify the moving path. This method is more in line with the real species movement.

Circuitscape4.0 is an open source program for simulating and analyzing landscape connectivity based on circuit theory. It operates in four modes: pairwise, advanced, one to all, and all to one. The first two modes can be used for grid and network data types, and the latter two modes are only applicable to grid data. In the first mock exam, paired pattern and many-to-one model are used to simulate. In pairing mode, all patches are grouped by every two patches. One input is 1 A current and the other node is grounded. The current values between each group are calculated respectively. After all simulations, the cumulative current values are combined to generate. The areas with high current values can be used as important functional corridors. In addition, we need to use the relevant modules of the linkage mapper plug-in to call the pairwise pattern to further analyze and filter the ecological corridor.

Based on the two models, this study optimizes the ecological corridor through land type classification and the cumulative resistance of the ecological corridor. When the ecological corridor identified by the two models has intersecting or overlapping parts, the difficulty of implementing the ecological corridor is comprehensively considered, and the priority to retaining the potential ecological corridor dominated by forest land, grassland, and water area, followed by cultivated land, bare land, and construction land, is given. For similar land types, corridors with less land occupation shall be reserved first. The ecological corridors with low resistance shall be reserved. In addition, the number of corridors in a certain area is large, and the corridors with excessive resistance shall be eliminated.

### 2.3.4. Determination of Ecological Nodes

The ecological node refers to the intersection of the consumption path and the shortest path of species migration. It is the weakest place of ecological function and plays the role of "stepping stone." This study takes the collection point of ecological corridor as the ecological node.

### 2.3.5. Ecological Network Connectivity

Using a graph theory and network analysis methods, this study evaluates the connectivity of the ecological network of the Yangtze Huaihe River Diversion Project (Anhui) and explores the effectiveness of its internal structure. Network closure (α), line point rate (β), network connectivity (γ), and cost ratio (c) are used to describe the connectivity of ecological network in this study. The formula is as follows:

\[
\alpha = \frac{l - v + 1}{2v - 5},
\]

\[
\beta = \frac{l}{v},
\]

\[
\gamma = \frac{l}{l_{\text{max}}},
\]

\[
c = 1 - \frac{l}{d}.
\]
where \( l \) represents the number of corridors, \( v \) represents the number of ecological nodes, and \( d \) is the total length of all corridors in the ecological corridor.

The value of \( \alpha \) is \([0, 1]\), which describes the loopable level of the ecological network. The closer the value is to 1, the more loops of the ecological network, and the stronger the material circulation and energy fluidity. When \( \beta < 1 \), it is the number of corridors corresponding to ecological nodes. When \( \beta = 1 \), there is a tree ecological corridor. Single loop ecological network; when \( \beta > 1 \), it is a complex ecological

### Table 4: Area statistics of MSPA landscape types.

| Landscape type | Area (m²)     | Percentage of prospect (%) |
|----------------|---------------|----------------------------|
| Core           | 11778751288   | 83.5                       |
| Islet          | 113089500     | 0.8                        |
| Perforation    | 375615000     | 2.7                        |
| Edge           | 1469453400    | 10.4                       |
| Loop           | 50352300      | 0.4                        |
| Bridge         | 113600700     | 0.8                        |
| Branch         | 199549800     | 1.4                        |

![Distribution of MSPA landscape types (current situation).](image)
network structure. In $[0, 1]$, it represents the interconnection degree of ecological nodes in the network. The larger the value, the higher the interconnection degree of ecological nodes. $C$ represents the input/output relationship. The lower its value is, the more favorable it is for the construction of ecological network.

3. Results

3.1. Ecological Source

3.1.1. Identification of Ecological Origin Based on MSPA.
The current core area in the study area is 1177875 hm$^2$, accounting for 83.5% of the total prospective area (Table 4). It is mainly distributed in the south of the Jianghuai Watershed, with the Huaihe River (Figure 2), with a good ecological environment. Compared with the area to the south of the Jianghuai watershed, there are few woodlands and grasslands in the north except rivers, which is not conducive to river protection and ecological corridor connection. Based on the theory of island biogeography proposed by Mac Arthur and Wilson, this study screened the important patches in the core area with an area of more than 100 hm$^2$ and extracted the patches with dpc >0.1, a total of 82 sources. Among them, there are nine scenic spots, including Balilihe national scenic spot, Chaohu national scenic spot, Zipeng Mountain provincial scenic spot and Tangchi provincial scenic spot. The National Forest Park includes Maokian River, Zipeng Mountain, Yanshan Mountain, Wanfoshan, Yefu Mountain, Tianjing Mountain, longmian Mountain, and Dalong mountain. The bridge area is an important channel...
connecting the core area, with a small area, accounting for only 0.8%. The branch line also has a certain connection function, accounting for 1.4%. The connectivity between the internal and external landscape of the foreground landscape patch is low, but some important areas can be extracted from the two as corridors for the area from the Yangtze River to the Huaihe River. The patch connectivity of isolated islands was low, accounting for 0.8%. Perforation is the inner edge of the core area, accounting for 2.7%. The edge is the transition area between the core area and the background, accounting for 10.4%. Ring roads are roads connecting the same core area, accounting for 0.4%. Isolated island, perforation, ring road, and bridge area account for a small area in the foreground, indicating that there are many large patches in the river diversion to Huaihe River Project (Anhui), including Huaihe River, Chaohu Lake, Yangtze River, and southern mountainous areas (Figures 3 and 4). The internal connectivity of the patches in the same source is low, the edges are broken, and they are easy to be disturbed by the external environment. According to the overall plan for ecological protection and tourism along the Yangtze River to Huaihe River project and the control scheme for land development and utilization, the newly excavated river and dredged river (Figure 5) belong to the core area, connecting the Yangtze River, Chaohu Lake, Wabu Lake, Wohe River, and Cihe River, which is conducive to the protection of water sources.

3.1.2. Distance Threshold Setting and Landscape Connectivity Index Analysis. Through the analysis of distance threshold gradient method, as shown in Figure 6(a), when the distance...
threshold is 50–400 m, the number of landscape connections (NL) of endogenous land in the study area is easy to increase with the increase of distance threshold, and the landscape component fraction (NC) decreases rapidly with the increase of distance threshold, indicating that the distance threshold in this interval is not suitable for describing the connection of landscape in the study area. When the distance threshold is 400–1500 m, the NC value begins to decline slowly, but the rising range of NL value does not change significantly. When the distance threshold is 1500–8000, the NC value begins to decline rapidly, but the NL value increases greatly, indicating that the distance threshold in this interval is not suitable to describe the connection of the landscape in this study area. When the distance threshold is greater than 8000, the landscape component value NC finally decreases stably to 1. It can be considered that the ecological patches in the study area are basically connected, and the distance threshold cannot be used as an appropriate distance threshold range. Based on this, the optimal distance threshold is 400–1500 m.

Combined with the equivalent global connectivity index (EC (IIC)), the equivalent possible connectivity index (EC (PC)) changes with the distance threshold. As shown in Figure 6(b), the distance threshold is 600–800 m, the equivalent global connectivity index (EC (IIC)) changes weakly, and (EC (PC)) is basically stable, indicating that the landscape stability in this distance threshold interval is good,
so the landscape connectivity analysis can be carried out. Finally, it is determined that the distance threshold of landscape connectivity in this study is 800 m.

3.2. Ecological Corridor

3.2.1. Analysis of Ecological Resistance Surface. From the current basic resistance surface (Figures 7 and 8), the forest land in the south of the Jianghuai watershed is widely distributed, with large patches such as Chaohu Lake, the Yangtze River, and Dabie Mountains. At the same time, the construction land is relatively concentrated, the overall resistance is small, and the connectivity is high, while the construction land in the North Plain is more and scattered, the forest land is scattered, the area is small, and it is greatly disturbed by human beings; therefore, the overall resistance is high and the connectivity is low. It can be seen from Figures 9 and 10 that the planned River Diversion Project (Anhui) reduces the resistance value of Huaihe River, Chaohu Lake, and other surrounding areas and improves the landscape connectivity of rivers and lakes along the line.

3.2.2. Ecological Corridor and Ecological Node. By superimposing the corridor results identified by the MCR model with the river corridor, 38 ecological corridors and 23 ecological nodes are constructed in the current area of the river diversion to Huaihe River project through the MCR model, the value of $\alpha$ is 0.39, indicating that the connectivity of the area from the Yangtze River to the Huaihe River is high, and the value of $\beta$ is 1.65 (>1), indicating that the constructed ecological network is complex and the connectivity of ecological corridors in the network is good. The value of $\gamma$ is 0.60, indicating that the ecological nodes are highly interconnected; the value of $C$ is 0.99, indicating that the cost of construction based on this study is high (Figures 11 and 12). The construction of 47 potential ecological corridors and 35 ecological nodes in the planning area of the river diversion to Huaihe River Project (Figure 13) connects

![Figure 6: Change of minimum patch area threshold setting in ecological source area.](image-url)
important ecological sources, greatly improves the landscape connectivity of ecological sources, avoids the intensification of habitat fragmentation, and greatly enhances the possibility of species movement in the north and South.

Through the comparative analysis of the current situation and planning, although 9 ecological corridors and 12 ecological nodes are added, the ecological network connectivity index values of $\alpha$, $\beta$, and $\gamma$ decreased by respectively...
Figure 9: Single factor resistance surface (planning).
Therefore, the Yangtze Huaihe River Diversion Project (Anhui) reduces the connectivity of the whole regional ecological network, and the barrier between the two banks of the river is also strengthened.

Based on the corridor results identified by superposition and river corridors, 165 ecological corridors and 76 ecological nodes in the current area of the river diversion to Huaihe River project are constructed through the circuit model, and the value of $\alpha$ is 0.61. It shows that the connectivity of the area from the Yangtze River to the Huaihe River is high, and the path of species migration and diffusion is large. The value of $\beta$ is $2.14 (>1)$, which shows that the constructed ecological network is complex and the connectivity of ecological corridors in the network is good. The value of $\gamma$ is 0.74, indicating that the ecological nodes are highly interconnected, and the value of $C$ is 0.99, indicating that the construction cost based on this study is high. According to the comprehensive analysis of the data, the ecological network constructed based on the circuit theory has good connectivity (Figure 14). Therefore, from the perspective of landscape connectivity, building ecological network based on circuit model is a better method. Based on the circuit model, 186 potential ecological corridors and 110 (Figure 15) ecological nodes are constructed in the planning area of the project. After the completion of the Yangtze Huaihe River Diversion Project (Anhui), 21 corridors and 34 ecological nodes have been added compared with the current situation. The values of $\alpha$, $\beta$, and $\gamma$ are 0.36, 1.69, and 0.57,
respectively. Compared with the current ecological network, the connectivity index decreased by respectively 0.25, 0.48, and 0.17. The connectivity index of the ecological network constructed based on MCR model decreased more obviously than that of the ecological network constructed based on MCR model. The circuit model better reflects the impact of the project on regional connectivity.

Through the analysis of ecological network connectivity index, the connectivity of ecological network constructed by circuit model is significantly higher than that constructed by MCR model. Considering the advantages and disadvantages of the two models in building ecological networks, based on the land use type and cumulative resistance value, the corridors with relatively large construction land and cumulative resistance value are screened and removed, and all ecological corridors are combined and redundant to obtain potential ecological corridors between ecological sources, a total of 214 ecological corridors and 116 ecological nodes (Figure 16). The value of $\alpha$ is 0.44. It shows that the connectivity of the area from the Yangtze River to the Huaihe River is high, and the path of species migration and diffusion is large. The value of $\beta$ is 1.84 (>1), which shows that the constructed ecological network is complex and the connectivity of ecological corridors in the network is good; the value of $\gamma$ is 0.63, indicating that the ecological nodes are highly interconnected. The value of $C$ is 0.99, and the first mock exam shows that the cost of constructing the ecological network based on this research is higher. Compared with the single ecosystem, the ecological network generated by the model is more connected. Meanwhile, it can reduce the
3.3. Optimization Strategy

3.3.1. Protect the Ecological Source. The ecological sources of the Yangtze River to Huaihe River Project (Anhui) are mainly distributed in the Huaihe River, Chaohu Lake, the periphery of the Yangtze River, and the southern mountainous areas, generally showing a distribution pattern of “more in the south, less in the north, and moderate in the middle.” Through the comparative analysis of the current situation and the planned landscape connectivity index, the river diversion to Huaihe River project runs through the north and south, improving the landscape connectivity of Chaohu Lake, Huaihe River, and other ecological sources. There are mainly 20 ecological source areas in the northern region, including Beifeihe River, Tianhe River, Balhe River, Xifeihu Lake, Jiaogang Lake, Gaotang Lake, Huangcangyu, Liangshan, Zaoshan, Longji Mountain, Maoxiandong, and Bagong Mountain, which account for 2.6% of the northern region. The connectivity is poor. Through planting trees and forests, returning farmland to lakes, mountain restoration, and expanding the patch node area, the connectivity of regional ecological sources is improved. There are 21 ecological sources in the central region, including Anfengtang, Wabu Lake, Dongpu Reservoir, Binhu, Chaohu, Huangpi Lake, Zipeng Mountain, Ziwei Cave, Yiping Mountain, Yefu Mountain, Gushan, Liushan, and Tianjiaing mountain, with an area of 10.9% and moderate connectivity. To
strengthen the connection between the ecological source and the surrounding core area patches, we should focus on the protection and construction of the ecological corridor connected with it to ensure the north-south connectivity of the ecological network. In the southern region, there are 42 ecological sources, including Fushan Mountain, Shangshanling Mountain, Yashan Mountain, Mingtang Mountain, Jushi Mountain, Jiangjunling Mountain, Xizi Lake, Zhusi Lake, Fengsha Lake, Huating Lake, Baidang Lake, Wuchang Lake, Bohu Lake, Daguan Lake, Longgan Lake, and the Yangtze River, with an area of 33.1%. The connectivity is good. The construction of nature reserves is strengthened and human interference activities are reduced. A buffer zone is set at a certain distance to continue to maintain and expand its ecosystem service function. Large rivers and lakes such as the Yangtze River, Huaihe River, and Chaohu Lake have played an important role in the structure and function of the project of diverting water from the Yangtze River to the Huaihe River. Sustainable protection should be carried out from many aspects, such as water pollution control, sewage interception and diversion, water quality improvement, aquaculture restriction, and water source protection. Baohe, Jiaogang Lake, Dongpu Reservoir, Binhu Lake, Huangcangyu, Zaoshan, Longji Mountain, and other adjacent towns are relatively small and vulnerable to urban expansion. These areas should strictly define the ecological and urban spatial boundaries, limit over development, and strengthen protection. The tourism nodes along the water conservancy project constructed by eight hubs and many ports define the project red line and ecological safety zone,

**Figure 13:** MCR model building ecological network (planning).
pay attention to pollution and noise reduction, reasonably plan the tour line, strengthen management and publicity, reduce the negative effect of human activities on the ecological environment, and protect biodiversity.

3.3.2. Ecological Corridor. From the comparative analysis of the current ecological corridor and the planned corridor, the landscape connectivity has been reduced, indicating that the project itself has a certain barrier effect on the connection between the sources. The ecological corridors of the river diversion to Huaihe River Project (Anhui) are mainly distributed in the south of the Jianghuai watershed. The landscape connectivity in the north of the Jianghuai watershed is low and the sources are scarce. Corresponding ecological sources should be added and the protection of the longer corridors should be strengthened; that is, adding ecological nodes in the longer corridors can effectively promote the flow of species and energy. In order to ensure the implementability of the construction of potential corridor, the landscape element components are further analyzed, and the reasonable dredging strategy is put forward. The grassland, water land, forest land, and cultivated land landscape elements in the study area are the main components of the potential corridor, which confirms the feasibility of the composition of the ecological network to a certain extent. In the North River water transmission section of the study area, the ecological corridors are mainly cultivated land, and there are almost no forest land and grassland, which is also the reason for the small number of corridors. In the Yangtze Huaihe River communication section of the study area, the ecological corridors are mainly cultivated land, followed by forest land and cultivated land.
and grassland. The small number of ecological corridors is due to its small scope. In the study area, the ecological corridors are mainly cultivated land, forest land, and grassland, and the number of ecological corridors is the largest, thanks to the good ecological environment. The overall number of ecological corridors dominated by water areas is small, because MSPA analysis is defined as prospect, and the analysis results take most water areas as ecological sources. In addition, the potential corridors dominated by different landscape element types should also be emphasized in the construction process: the potential corridors dominated by grassland and forest land should focus on establishing the foundation for the ecological stability of the corridors through rich vegetation communities, so as to realize the stability of the regional microenvironment and the stability of the potential corridors. For the potential corridor dominated by water and cultivated land, the "safe haven" along the line should be built through planting to create the possibility of species migration in the corridor. On this basis, an ecological corridor based on natural rivers and lakes will be formed, the "three corridors" will be constructed by the main ecological corridor leading from the river to the Huaihe River, the Shaying River ecological corridor, and the Wohe River ecological corridor, the "two belts" will be constructed by the Yangtze River ecological conservation belt and the Huaihe River ecological conservation belt, the agricultural production ecological function area between the Shaying River, Wohe River, and xifeihe River, and the flood regulation and storage—waterfowl protection ecological function area in the middle reaches of the Huaihe River, Hefei urban pollution prevention and control—environmental protection ecological functional area around Chaohu Lake, Caizi Lake—Wanjiang

Figure 15: Construction of ecological network by circuit model (planning).
wetland ecological protection ecological functional area, establishes Chaohu Lake as the ecological core and connects the two major water systems of Wabu Lake and Caizi lake, and large ecological areas of Wuding mountain—Fenghuangshan—Fushan, Yinping mountain, Gongan Mountain—Guishan—Yizhang mountain,Zipeng Mountain and Bagong mountain. Finally, an ecological spatial structure of “three corridors, two belts, four areas, one core, two lakes, and six areas” will be formed to improve the overall connectivity and stability of the ecological network (Table 5).

3.3.3. Ecological Node. The ecological source area in the north of the Jianghuai Watershed in the study area is small, the landscape connectivity is low, and the ecological corridor is long. Ecological nodes should be appropriately increased to improve the effectiveness of network connection. In the future planning, it should be considered to strengthen the protection of ecological nodes and increase the number and area of nodes with higher ecological functions in areas with less corridors and sources. It is found that the landscape elements of ecological nodes that need to be protected can be divided into the following two categories: the first category is the water ecological patches dominated by wetlands and water bodies. For this type of potential patch, the priority is to protect the integrity of the current water body and wetland. The main strategy is to set up wetland ecological protection areas, impose restrictions on the development of land, and carry out greening restoration and ecological infrastructure construction around, so as to increase the

Figure 16: Optimizing ecological network by integrating MCR model and circuit model.
construction.zZ_heresultsshowthat finally discusses the optimal way of ecological network and the construction and evaluation of ecological network, and model to identify and extract the source, uses connectivity index to identify and extract the source, uses connectivity index to return farmland to grassland and grassland to forest as the main landscape elements. zZ_his type of regional habitat, so as to greatly improve the flow of species between patches. The ecological patches in the Anhui from the Yangtze River to the Huaihe River are large, but the connectivity between patches is poor, and the important ecological corridors and ecological nodes constructed in this study make up for the above deficiencies. In addition, MSPA-based methods have different analysis results on different landscape scales, and low resolution may lead to the mis-classification of smaller pixels in the landscape. The study area is an important ecological function area. In order to avoid the loss of some important landscape types, the study scale is 30 m × 30 m, and the optimal scale of constructing ecological network in the study area needs to be further studied.

In the planning and construction of ecological network, only the land changes caused by the river diversion to Huaihe River Project (Anhui), the river diversion to nests, the river Huaihe River communication, and the river water north transmission are considered, and the land planning of the whole river diversion to Huaihe River area is not considered, which may have a certain impact on the ecological network planning. Taking the administrative boundary as the boundary of the study area, the edge effect is ignored. In the future, in the practice of building ecological network, we also need to strengthen communication and cooperation with adjacent regions. We should try our best to maintain the integrity of habitat patches and the stability of ecological network through policy coordination or planning and build a joint ecological network with regional connectivity.

### 5. Discussion

Ecological network can effectively improve the fragmentation of regional habitat, so as to greatly improve the flow of species between patches. The ecological patches in the Anhui from the Yangtze River to the Huaihe River are large, but the connectivity between patches is poor, and the important ecological corridors and ecological nodes constructed in this study make up for the above deficiencies. In addition, MSPA-based methods have different analysis results on different landscape scales, and low resolution may lead to the mis-classification of smaller pixels in the landscape. The study area is an important ecological function area. In order to avoid the loss of some important landscape types, the study scale is 30 m × 30 m, and the optimal scale of constructing ecological network in the study area needs to be further studied.

In the planning and construction of ecological network, only the land changes caused by the river diversion to Huaihe River Project (Anhui), the river diversion to nests, the river Huaihe River communication, and the river water north transmission are considered, and the land planning of the whole river diversion to Huaihe River area is not considered, which may have a certain impact on the ecological network planning.

Taking the administrative boundary as the boundary of the study area, the edge effect is ignored. In the future, in the practice of building ecological network, we also need to strengthen communication and cooperation with adjacent regions. We should try our best to maintain the integrity of habitat patches and the stability of ecological network through policy coordination or planning and build a joint ecological network with regional connectivity.
Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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