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Construction and Optimization of Ecological Security Pattern of the Henan Section in the Yellow River Basin

Tao Liu[1,*], Junhua Zhou[1], Shichao Li[1], Yifei Wang[1]

[1]*College of Resources and Environment, Henan University of Economics and Law, Zhengzhou, China*
[*]*Corresponding author*

Abstract: *The ecological protection and high-quality development of the Yellow River basin have become a major national strategy, necessitating the scientific construction and optimization of the ecological security pattern. Taking the Henan section of the Yellow River basin as the study area, this research integrates the "value-demand-risk" evaluation results to select ecological source areas and utilizes circuit theory to identify important ecological corridors and key ecological nodes, thus constructing an ecological security pattern. The optimization of the ecological security pattern is based on resource allocation, aiming to ensure more benefits for residents from the ecosystem. The results indicate the following: (1) The overall distribution of ecological system service value and ecological sensitivity in the Henan section of the Yellow River basin shows a west-high-east-low pattern, while the spatial distribution of ecological demand and ecological disturbance displays an east-high-west-low pattern. (2) The comprehensive ecological resistance values in the study area range from 4.75 to 545.05. High-value areas are mainly concentrated in the central-eastern regions with high human activities and fragile ecological environments, while low-value areas are mainly found in the western regions with relatively high vegetation coverage and favorable natural environmental conditions. (3) Before optimization, there were 125 ecological corridors in the study area, with a total length of 4283.52 km and 63 ecological nodes. After optimization, there are a total of 156 ecological corridors, with a total length of 4677.61 km, and 88 ecological nodes.*

Keywords: *ecological security pattern; circuit theory; Yellow River Basin*

1. Introduction

The Yellow River Basin is an important ecological barrier and economic belt in China, and an important "ecological corridor" linking the eastern and western parts of the country [1], which has an important strategic position in China's development [2]. China's ecological and environmental problems in the watershed characteristics of the increasingly prominent [3], watershed ecosystems have become coupled "geomorphological - hydrological - ecological - humanistic" complex system [4]. After long-term exploitation and rapid economic growth, the Yellow River Basin has caused great damage to the natural ecological environment [5]. The Henan section of the Yellow River Basin is an important part of the Yellow River Basin, and its human-earth conflicts are mainly manifested in the following ways: ① complex geomorphological types, large topographic undulations, and unstable ecosystem structure; ② natural disasters are intertwined with runoff depletion, abundance and decrease, and extreme precipitation induced secondary disasters [6-8]. Its ecological problems include: ① uneven distribution of carbon stocks: vegetation and soil organic carbon density in the horizontal direction and elevation gradient spatial differentiation is obvious [9]; ② soil erosion: water and sand content imbalance, the vegetation cover is reduced [8]; ③ land sands: degradation of vegetation, land production capacity decline [10]. Therefore, there is an urgent need to build an optimised ecological security pattern to promote ecological protection and high-quality development in the Yellow River Basin.

Ecological safety pattern originated from foreign landscape planning [11], aiming to provide healthy and sustainable ecosystem services [12]. At present, the construction of ecological security pattern at home and abroad has formed a relatively perfect mainstream system of "source identification - resistance surface construction - corridor node extraction", and carried out research on different scales [13,14], objects [15,16] and perspectives [17,18]. The identification of ecological source areas plays a decisive role in the construction of regional ecological security pattern, and currently its identification mainly

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relies on existing protected areas [19], morphological spatial pattern analysis [20] and ecological function evaluation [21,22], among which the construction of ecological function evaluation system is mostly based on ecosystem service value [23], ecological sensitivity [24], suitability [25], disturbance [18], and ecosystem service supply and demand [26] perspectives. The mainstream methods for setting resistance surfaces include assigning values to landscape types [23-26], as well as measuring ecosystem services or ecological footprints [27,28]. Ecological corridors are the pathways of least resistance for species dispersal flows, and commonly used methods include graph theoretic approaches [29], least cumulative resistance models [30], circuit theory [31] and ant colony models [32]. Ecological nodes refer to the key points of important zones in ecological corridors, and have gradually developed different concepts such as ecological pinch points [33,34], obstacle points [34], rupture points [35] and strategic points [36]. The rational use of the "source- resistance surface-corridor and node" framework is conducive to the protection of regional ecological health and sustainable socio-economic development. The rational utilization of the “source-resistance-corridor and node” framework is beneficial for the regional ecological health protection and socio-economic sustainable development. The Henan section of the Yellow River basin is located in the middle and lower reaches of the Yellow River, playing a crucial role in linking the upstream and downstream regions. It is also an important area for water conservation and ecological replenishment in Henan Province, directly impacting the ecological security of both Henan Province and the entire Yellow River basin. The construction and optimization of the ecological security pattern in the Henan section of the Yellow River basin can deepen the connection between the ecological security at the ecosystem and human well-being levels.

2. Study area and data sources

2.1. Overview of the study area

The Yellow River basin (Henan section) is located in the central and northern parts of Henan Province, China (33°N～36°N and 111°E～116°E)[37]. It runs through eight cities in Henan Province, including Zhengzhou, Kaifeng, Luoyang, Xinxiang, Jiaozuo, Puyang, Sanmenxia, and Jiyuan. The total land area is about 5.74×104 km^2[38], with a main channel length of 711 km and a total basin area of about 3.62×104 km2. The region has a warm temperate continental monsoon climate, with an average annual rainfall of 500-900 mm and an average annual temperature of 12-15°C[39]. The terrain is higher in the west and lower in the east, and the main land use types are cultivated land, woodland, and water (see Figure 1). As of 2020, the permanent population in the Yellow River basin (Henan section) was about 39.8356 million, with a total GDP of approximately CNY 2.8446 trillion and a per capita GDP of around CNY 71,408. In recent years, due to intense human activities and continuous degradation of natural resources, the ecological environment in the region has deteriorated, leading to serious soil erosion and hindering the sustainable development of the Yellow River basin (Henan section).

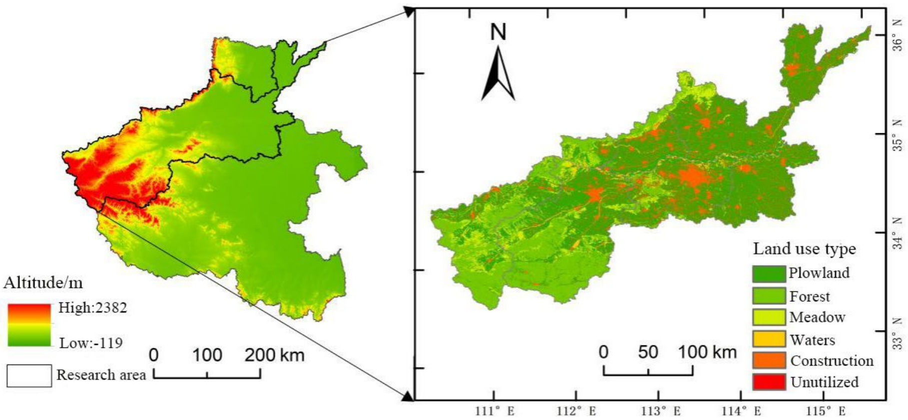

Figure 1: Summary map of the study area.

2.2. Data sources

The land use data (2020 period), normalized difference vegetation index (NDVI), soil erosion, GDP, and population spatial distribution data are sourced from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences. The digital elevation model (DEM) data with a resolution of 30m is sourced from the Geospatial Data Cloud, which includes elevation, slope, and other related data; road traffic, settlement and water system data were obtained through the OpenStreetMap site by Crawling POI data was obtained; The ecological protection areas (boundary vector data of nature reserves) originate from the geographical information database of the China Nature Reserves Specimen Resources Sharing Platform.; humanistic landscape and natural landscape data originated from the list of A-class tourist attractions of Henan Provincial Department of Culture and Tourism and Gaode Map; administrative vector data originated from the administrative area data of the National Geosystems Data Sharing Platform in 2019.

3. Research methodology

3.1. Source location identification

This habitats for plants and animals, ecological source areas have relatively stable ecological structures and functions, and provide high-quality ecosystem services and products for human beings while maintaining the stability of regional ecosystems. In this paper, we constructed an evaluation index system for ecosystem service value, ecological risk and ecological demand, combined with hierarchical analysis and spatial superposition analysis to obtain a comprehensive evaluation spatial distribution map, and used particle backpropagation to identify ecological source areas.

The preliminary ecological source area divided according to the natural discontinuity method, there are many scattered patches with small area and weak connectivity, which are unable to give full play to the ecological function and provide ecological benefits, and belong to the inferior patches [31]. Based on the idea of the inverse method, the preliminary ecological source area was generated as a raster map of the ecological source area with landscape granularity of 100m, 200m, 400m, 600m and 800m, respectively, and then the patch density (PD), the number of patches (NP), the aggregation index (AI), the landscape shape index (LSI), the cohesion index (COHESION), the separativity index (SPLIT), the cohesion index (COHESION) and the separativity index (SPLIT), calculated by the Fragstats software, were used. (SPLIT).

Based on the actual land use situation in the Henan section of the Yellow River basin and referring to the research findings of Xie Gaodi et al. [40], we have made adjustments to the equivalent factors of the ecosystem service value per unit area in the study area and have therefore determined the ecosystem service value per unit area in the research region (Table 1). By combining this with the ecosystem service value model proposed by Costanza et al. [41] (Equation 1), we can obtain the total value of the ecosystem.

$$ESV = \sum \left(\mathrm{uc}_{\mathrm{k}}, A_k \right) \tag{1}$$

ESV denotes the total ecosystem value; uck denotes the coefficient of ecological service value of k ecological sites; Ak denotes the area of k ecological sites.

Table 1: Value table of ecological services in the Henan section of the Yellow River basin.

Ecosystem services	Value of ecosystem services				
	Plow	Forest	Meadow	Construction	Waters
Gas regulation	29.09	93.79	52.14	26.05	19.33
Climate regulation	31.29	268.33	116.42	42.60	17.08
Clean up the environment	12.90	81.76	41.20	37.48	7.80
Food production	29.48	16.57	22.80	22.76	21.46
Raw material production	12.91	29.64	19.63	10.89	8.81
Water supply	6.35	11.31	9.35	73.91	4.12
Soil conservation	16.86	211.83	83.86	22.69	6.99
Maintaining nutrient cycling	4.72	9.11	7.01	3.76	3.23
Biodiversity	13.33	102.94	48.88	24.98	7.44
Aesthetic landscape	6.49	44.55	22.53	14.94	3.76
Total value	163.42	869.83	423.82	280.06	100.02

Ecological risk assessment is a comprehensive evaluation of the intrinsic stability and extrinsic resistance of ecosystems [18], including ecological sensitivity assessment and ecological interference assessment, ecological sensitivity refers to the degree of sensitivity of ecological elements to disturbances, and ecological interference is used to indicate the degree of interference of anthropogenic activities on the ecological environment as well as the possibility of bringing impacts to the ecological environment [42]. Demand for ecosystem services refers to human consumption or preference for the services provided by ecosystems [43]. We have utilized expert scoring and Analytic Hierarchy Process (AHP) to determine the weights of evaluation factors. These factors are then divided into five levels using the natural break method. Finally, by performing spatial analysis and overlaying the evaluation factors, we can generate the distribution maps of ecological risk and ecological demand in the Yellow River basin (Henan section) , as shown in Table 2.

Table 2: Ecological risk and demand table of the Henan section of the Yellow River basin.

Evaluation factors	evaluation factor	high value	high value	median value	lower value	low value	weights
ecological sensitivity	altitude	>1200m	800~1200m	500~800m	250~500m	<250m	0.08
	elevation	>35°	25°~35°	15°~25°	8°~15°	<8°	0.09
	Land class	Forest, waters	Meadow	\	Plow	Construction, Unutilized	0.12
	soil erosion	\	dissociation	moderately	mild (symptoms etc)	mildness	0.22
	Vegetation cover index	0.75~1	0.65~0.75	0.5~0.65	0.35~0.5	0~0.35	0.17
	Natural scenic spot	<500m	500~1000m	1000~2000m	2000~4000m	>4000m	0.25
	Cultural scenic spot	<50m	50~100m	100~200m	200~400m	>400m	0.07
ecological vulnerability	Distance to railway and highway	<50m	50~100m	100~200m	200~500m	>500m	0.17
	Distance to national and provincial roads	<30m	30~50m	50~100m	100~200m	>200m	0.13
	Distance to residential place	<400m	400~600m	600~800m	800~1000m	>1000m	0.25
	Land class	building site	\	Cropland, non-building land	\	Woodland, grassland, water	0.45
ecological necessity	Population density (persons/km^2)	>4000	2000~4000	800~2000	300~800	<300	0.36
	Economic density (billion yuan/km^2)	>8	3.6 to 8	12~3.6	0.4~1.2	<0.4	0.31
	Degree of land use	>3.5	3~3.5	2.5~3	2~2.5	<2	0.33

3.2. Resistance surface construction

Ecological resistance surfaces are the foundation for building ecological corridors and can reflect the difficulty of species migration or the spatial transfer of ecological processes [44]. In this paper, eight indicators, including land use classification, elevation, slope, vegetation cover index, railway and high-speed distance, national and provincial highway distance, settlement distance and water distance, were selected as resistance factors. The Analytic Hierarchy Process (AHP) is used to assign weights, and spatial overlay analysis is employed to construct ecological resistance surfaces (Table 3).

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Table 3: Ecological resistance factors and their coefficients

Drag factor	Grading Indicators	drag coefficient	weights	drag factor	Grading Indicators	drag coefficient	weights
Land use type	woodland	1	0.25	Railway high speed distance	>500m	1	0.07
	grassland	25			200~500m	300	
	arable land	50			100~200m	500	
	unused land	800			50~100m	700	
	building site	1000			<50m	900	
Altitude	<250m	10	0.15	Distance from national and provincial roads	>200m	1	0.05
	250~500m	20			100~200m	100	
	500~800m	40			50~100m	200	
	800~1200m	60			30~50m	300	
	>1200m	80			<30m	500	
Elevation	<8°	1	0.12	Distance to settlements	>1000m	1	0.06
	8°~15°	100			800~1000m	300	
	15°~25°	200			600~800m	500	
	25°~35°	300			400~600m	700	
	>35°	500			<400m	900	
Vegetation cover index	0.75~1	1	0.2	Distance to water	<50m	10	0.1
	0.65~0.75	50			50~100m	30	
	0.5~0.65	100			100~300m	50	
	0.35~0.5	500			300~800m	70	
	0~0.35	900			>800m	90	

3.3. Corridor Extraction

Ecological corridors are paths of least cumulative resistance that are laid out linearly or in bands in ecological environments, communicating and connecting ecological sources, and that are capable of accommodating the dispersal, migration and exchange of species. In the theory of circuit theory, the combination of random walk theory and circuit theory incorporates the principles of ecological movement. In this framework, landscapes are seen as conductive surfaces, where landscape types that facilitate species movement are assigned lower resistance, while those that hinder species movement are assigned higher resistance. This approach helps understand the movement of species or gene flow processes in the context of landscape connectivity [45]. Based on the principles of circuit theory, this study utilizes the "Build Network and Map Linkages" tool in Linkage Mapper 2.0 to extract important and potential ecological corridors within the study area. The tool takes inputs such as ecological source areas, ecological resistance surfaces, and a carefully determined corridor threshold value, which in this case is set as 100,000m. Through multiple iterations and testing, the tool identifies and maps the important ecological corridors and potential ecological corridors in the study area.

3.4. Ecological nodes

Ecological nodes include ecological pinchpoints and ecological barrier points. Ecological pinchpoints are areas of high current density through which ecological processes flow, which are very important for regional ecosystem connectivity and are the key objects of ecological protection; Ecological barriers refer to the areas within corridors that hinder species migration, and removing them can enhance connectivity between ecological source areas. The Circuitscape open-source program, based on circuit theory, is used to identify ecological pinch points and ecological barriers. The Pinchpoint Mapper and Barrier Mapper tools in Linkage Mapper are used to recognize ecological pinch points and ecological barriers, respectively.

3.5. Buffer analysis methods

The buffer analysis method establishes an influence area around target points, lines, or polygons based on a given distance and analyzes the spatial impact of objects [46]. In this study, the buffer analysis method is employed to analyze the influence range of ecological sources and ecological corridors, and to optimize the Ecological Service Providers (ESP) based on ecological resource matching principles. Based on the concept of a "15-minute loop," the daily travel distance of residents is selected to represent

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the impact radius of ecological sources and ecological corridors, ensuring that residents have access to more ecological resources. Wu Xia'an [47] suggests that the travel distance within a 15-minute living circle is approximately 800 meters to 1100 meters. Based on this, the buffer radius for ecological sources and modified sources is set at 1100m and 800m, respectively. The buffer radii for key corridors, important corridors, general corridors, potential corridors, and modified corridors are set at 1100m, 1000m, 900m, and 800m, respectively.

4. Results and analyses

4.1. Ecological source site identification

All four ecological conditions in the Henan section of the Yellow River Basin show obvious spatial heterogeneity, as shown in Figure 2. Among them, the ecosystem service value and ecological sensitivity as a whole showed the distribution characteristics of high in the west and low in the east, and the ecological demand and ecological interference as a whole showed the spatial distribution characteristics of high in the east and low in the west, which is related to the resource endowment and social activities in the study area. The terrain in the middle and eastern part of the study area is flat, where urban land, rural settlements and arable land are concentrated, with intense human activities, low vegetation cover and high ecological demand and disturbance; high ecosystem service value is concentrated in the river area, which, as the main ecological land, is the main area to guarantee the ecological functions of climate regulation, watershed nourishment and the maintenance of biotic nutrients; the western part is located in the west Henan mountainous area, with high altitude and high land value. The western part is located in the mountainous area of western Henan, with high altitude, and the land use type is dominated by woodland and grassland, with relatively high ecosystem service value and sensitivity.

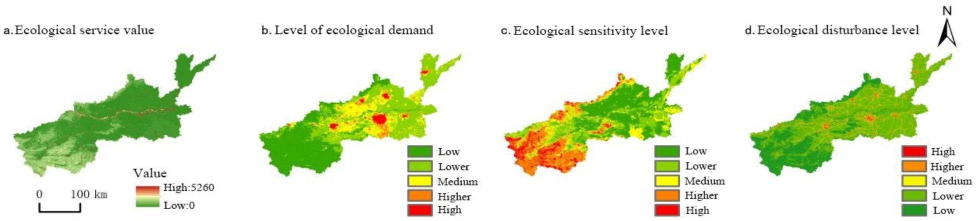

Figure 2: Ecological value, demand and risk map of the Henan section of the Yellow River Basin.

The ecological importance and ecological source areas of the Henan section in the Yellow River Basin are illustrated in Figure 3. The ecological importance in the study area shows a distribution pattern of higher importance in the western region, followed by the central region, and then the eastern region, and the ecological importance rank of the central-eastern region shows the characteristics of small area and fragmentation, which is related to the local human activities. There are many fine and fragmented patches in the preliminary ecological source area, and these patches need to be selectively deleted as an inferior landscape type.

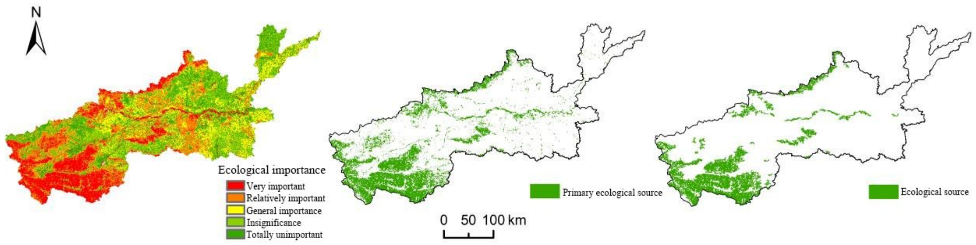

Figure 3: Ecological importance and source map of the Henan section of river basin.

The results of landscape pattern indices at different granularity levels are shown in Figure 4. The changes of NP, PD and LSI tend to level off when the landscape granularity is 400m, COHESION tends to be stable at 600m, but SPLIT has a large increase at 600m. Therefore, combining the change characteristics of each landscape pattern index, the landscape granularity of 500m was selected as a reference to inversely select the ecological source of optimal landscape connectivity. In terms of quantity, the Henan section of the Yellow River Basin has a total of 43 ecological source areas, covering an area of 8541.33 square kilometers, which accounts for 14.88% of the total study area. In terms of spatial distribution, the ecological source areas cluster in the southwestern part, form a belt-like distribution in the central region, while the eastern part lacks ecological source areas with rich ecological functions and stable ecosystems.

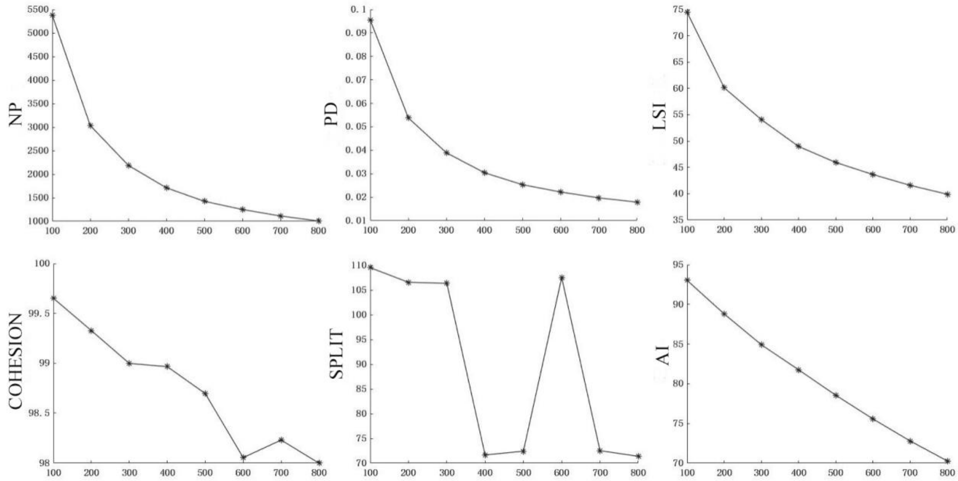

Figure 4: Landscape pattern index of different grain size levels.

4.2. Ecological security pattern construction

The comprehensive ecological resistance surface and ecological corridors in the study area are shown in Figure 5. The values of the comprehensive ecological resistance range from 4.75 to 545.05, with high values predominantly found in the central and eastern regions where human activities are concentrated and the ecological environment is fragile. High-resistance networks are formed between residential and industrial areas, which disrupt the already fragile ecological processes. Low values are mainly distributed in the western region with relatively high vegetation coverage and better natural environmental conditions. Ecological restoration and management in this area are beneficial for species migration and dispersal.

In terms of the spatial distribution of ecological corridors, they mainly extend from north to south, showing a “three-horizontal and four-vertical” distribution pattern. There are a total of 125 ecological corridors, with a total length of 4283.52 kilometers, including optimal ecological corridors and potential ecological corridors. Based on the centrality of the corridors, the optimal ecological corridors are divided into three categories: key corridors, important corridors, and general corridors. There are 52 key corridors with a length of 339.24 kilometers, mainly distributed in Luoyang, Jiyuan, and Sanmenxia. There are 29 important corridors with a length of 1064.32 kilometers, mainly concentrated in the central region, from Jiaozuo to Zhengzhou, Jiyuan to Luoyang, with breakpoints along the Yellow River water system. There are 14 general corridors with a length of 1201.31 kilometers, mostly distributed in the eastern and western regions. These corridors have longer distances and require stronger maintenance to ensure smooth species migration. There are 30 potential ecological corridors with a length of 1678.65 kilometers, mainly distributed in the grassland areas outside the research area and scattered near ecological source areas.

In this study, ecological nodes were identified based on circuit theory. Areas with high circuit density were selected as ecological pinch points. A total of 63 ecological pinch points were identified in the study area, mostly located in the central region, mainly along important corridors and general corridors. Among them, Zhengzhou has the highest number of pinch points, totaling 26. Overlaying the ecological resistance surface analysis reveals that the ecological pinch points are located in areas with lower resistance values, highlighting their important role in ecological connectivity and providing favorable ecological space for species migration and habitat.

Ecological obstacle points refer to areas with high ecological resistance and intense human activities, which need to be strengthened for restoration. There are a total of 17 ecological obstacle points, and the obstacle points are mainly distributed in the corridor break, there are more obstacle points at the Yellow River system, which needs to strengthen the pollution control of rivers and lakes, and the obstacle points at the edge area of the study area are mainly located in the woodland area, which needs to strengthen the implementation of the measures of grass nursery and forestry.

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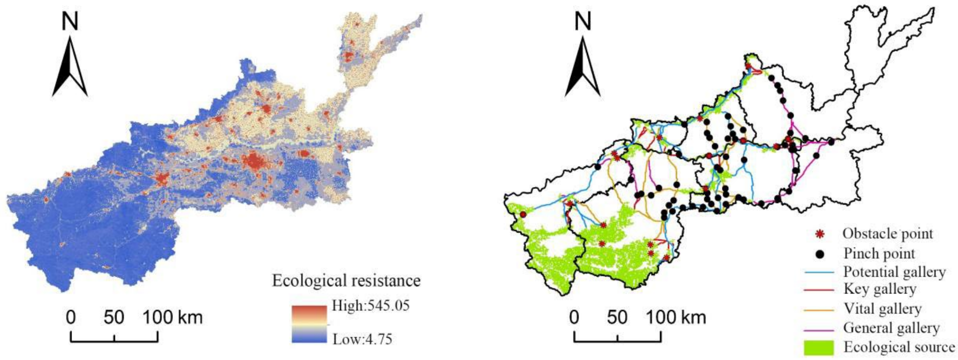

Figure 5: Ecological resistance and ecological security pattern map.

4.3. Optimisation of ecological security patterns

From the perspective of ecological resource matching, based on the constructed Ecological Service Providers (ESPs), buffer analysis is conducted on ecological source areas and ecological corridors. The buffer results are then overlapped with the distribution of residential areas within the study area, resulting in the coverage range of existing ecological resources and ecological corridors around residential areas. From Figure 6, it can be seen that the ecological impact coverage is better in the southwestern part, while it is lower in other areas. In other words, people living in the central and eastern regions will not be able to enjoy the ecological benefits brought by the constructed ESPs within their "15-minute living zone." Therefore, the constructed ESPs are limited in terms of ecological resource matching. Many urban residents have difficulty accessing ecological resources and corridors. Based on the residential areas that are not covered by source-corridor impact zones, high ecological importance areas are selected as modified source areas, and routes with low resistance values and consistency are selected as modified corridors. After optimizing the ecological security pattern, a certain number of additional ecological source areas and corridors are added to ensure that residents within the study area can enjoy the results of ESP construction and promote the sharing of ecological resources.

After optimisation, there are 55 ecological source sites with an area of 10,365.39 km^2, accounting for 18.06% of the total area of the study area, with an increase of 1,824.06 km in area2. Most of the new ecological source sites are of the type of land for settlements, which are in the densely populated places and ecological high-demand areas to make up for the lack of ecological sources in the eastern part of the country, and to effectively improve the stability of ecosystems, maintain the ecological health of the region, and protect the biodiversity, so that the ecological security pattern can be better improved. This will effectively enhance ecosystem stability, maintain regional ecological health and protect biodiversity, thus better improving the ecological security pattern. The optimised ecological corridors are 156 in total, crisscrossing the region, with a total length of 4677.61 km. 31 new corridors have been added, with an increase of 394.09 km in length, and most of the new corridors are located in the north-eastern part of the region. Among them, there are 121 optimal ecological corridors, 26 new ones, with a length of 2,775.86 kilometres, and 35 potential ecological corridors, 5 new ones, with a length of 1,901.73 kilometres. The newly added corridors mainly enhance the connectivity of the ecosystem as a whole, reduce the resistance value, and promote the energy flow of species, thus slowing down the pressure of socio-economic development on the demand of the ecosystem. There are 88 optimised ecological pinch points, with an increase of 25 pinch points, and most of the new pinch points are distributed in the northeastern city of Xinxiang, with sporadic distribution in other cities, which strengthens the ecological functions connecting different source patches and reinforces the fragile zones of ecological circulation; and 20 optimised ecological obstacles, with an increase of 3 obstacles, are added to the vicinity of the Yellow River system, which needs to be focused on managing the pollution of the water system and maintaining ecological security.

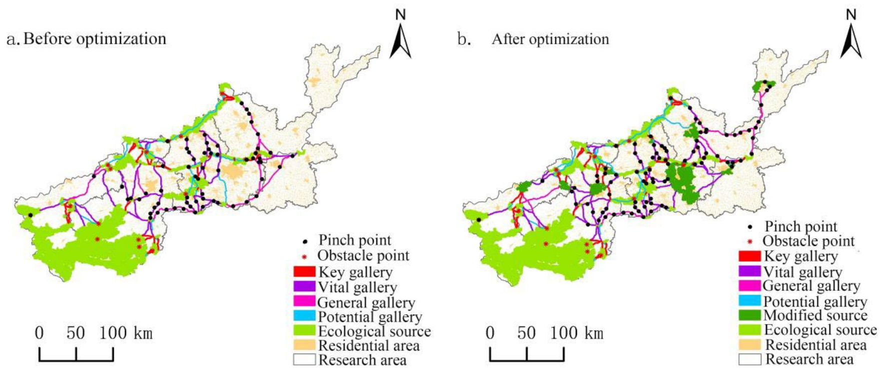

Figure 6: Comparison of ecological security pattern before and after optimization.

5. Conclusion and Recommendations

5.1. Conclusion

(1) The overall distribution of ecosystem service value and ecological sensitivity in the Henan section of the Yellow River Basin exhibits a west-high and east-low pattern. The spatial distribution of ecological demand and ecological disturbance shows an east-high and west-low pattern. This pattern is related to the resource endowment and social activities within the study area. The distribution of ecological significance in the study area follows a pattern of higher significance in the western region, followed by the central region and then the eastern region. In the central and eastern regions, the ecological significance shows characteristics of smaller area and fragmentation, which is related to local human activities.

(2) The comprehensive ecological resistance value in the study area ranges from 4.75 to 545.05. High resistance values are predominantly found in the central and eastern regions where human activities are concentrated and the ecological environment is fragile. High-resistance networks are formed between residential and industrial areas, disrupting the already fragile ecological processes. Low resistance values are mainly distributed in the western region with relatively high vegetation coverage and better natural environmental conditions.

(3) The ecological corridors before optimization mainly extend longitudinally from north to south, showing a distribution pattern of three horizontal and four vertical corridors. There are a total of 125 corridors with a total length of 4283.52 kilometers. Among them, there are 52 key corridors with a length of 339.24 kilometers, 29 important corridors with a length of 1064.32 kilometers, 14 general corridors with a length of 1201.31 kilometers, and 30 potential ecological corridors with a length of 1678.65 kilometers. Additionally, 63 ecological pinch points were identified. After optimization, 31 new ecological corridors were added with an increased length of 394.09 kilometers, primarily distributed in the northeast. Among them, the optimal corridors increased by 26 with a length of 2775.86 kilometers, and 5 potential corridors were added with a length of 1901.73 kilometers. There was an increase of 25 ecological pinch points, most of which were located in Xinxiang City in the northeast, while others were sparsely distributed in other cities.

5.2. Recommendations

By optimizing the ecological source areas, ecological nodes, and ecological corridors, and integrating major mountain ranges such as the Taihang Mountains and Funiu Mountains, as well as the natural background of the Yellow River Basin water system, the optimization strategy for the ecological security pattern in the Henan section of the Yellow River Basin is proposed based on the optimized ecological security pattern, referred to as the “two zones and three screens”. The ecological source areas mainly include the water conservation ecological function zone of the Funiu Mountains in the western region, the ecological function zone for the construction of the Puyang oil base, the ecological barrier for urban construction and development in the central region, the ecological barrier for lakes and wetlands in the Yellow River Basin, and the ecological barrier for biodiversity conservation in the northern region of the Taihang Mountains.

The water-source conservation ecological function area of the western Furniu Mountains is an important ecological source, the region is a well-preserved natural ecological mountain range, one of the soil and water protection forest species of special significance, a complex forest ecosystem, with the ecological, economic and social benefits commonly found in forests, most notably with the ecological services of conservation and protection of water sources, flood control and peak reduction, prevention of soil erosion, purification of water quality and regulation of the climate. Function, this part of the region is relatively large altitude, there are some tourism development industry, need to focus on maintaining the ecological environment of the tourism industry, implement the regional ecological corridor, maintain a stable ecological structure system. Puyang city oil base construction ecological function area is located in the core area of town development, the region is a relatively arid area, there are oil leakage pollution of groundwater, for the problem should be built sewage treatment plant, at the same time should strengthen the sewage treatment reuse, to achieve sewage resource to alleviate the water resources of Puyang city tense situation, to enhance the environmental carrying capacity of the ecological and economic zone in Puyang city. Central town construction and development of ecological barriers, the region's intense human activities, rich arable land resources, focusing on promoting farmland improvement, vigorously develop ecological agriculture, to provide a guarantee for regional food production, while focusing on the protection of ecological resources, strengthen the natural recovery of the regional vegetation, enhance the stability of the ecosystem and ecosystem service function. The ecological barrier of lakes and wetlands in the Central Yellow River Basin, which has serious soil erosion, can be targeted to carry out the delineation of buffer zones in the Central Yellow River Basin and the ecological restoration of water sources, while safeguarding the ecological water demand, reducing irrational human activities, and strengthening the protection of wetlands as a source of water. Ecological barrier for biodiversity protection in the northern Taihang Mountains, with high and steep slopes in the Taihang Mountains, exposed rocks and sparse vegetation, it should be suitable for forest planting, strengthening forest and grass species and enhancing biodiversity, and at the same time, increasing the construction of ecological woodland along the route and enriching biological resources, so as to play the role of ecological regulation in the regional environment.

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