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Analysis of Green Infrastructure Network Pattern Change in Zhengzhou Central City Based on Morphological Spatial Pattern Analysis

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ABSTRACT:

Green infrastructure is generally regarded as an effective way to maintain regional ecological security, and its construction method plays an essential role in its function realization. In this study, the central urban area of Zhengzhou was taken as the research area. The land use type maps of the study area were obtained through the supervised classification of TM/ETM Remote sensing image data in 2007, 2011, 2015, and 2019. The Green Infrastructure (GI) in the study area was obtained by Morphological Spatial Pattern Analysis (MSPA) based on the landscape connectivity index and landscape map theory. The landscape connectivity of the core area was classified and quantitatively evaluated. Then, the potential ecological corridors were extracted and analyzed. The GI pattern change research based on MSPA, landscape connectivity, and map theory provided a new framework for analyzing GI pattern change. Finally, the spatial structure of green infrastructure planning in Zhengzhou central city is obtained, and the optimization strategy of network structure is proposed. The research results can provide references for the planning and optimization of GI networks in the study area and have particular reference significance for the planning and construction of GI networks in other areas.

Keywords: Landscape architecture; Morphological Spatial Pattern Analysis; Green Infrastructure; Zhengzhou central city

Análisis de los cambios de patrones en las redes de infraestructura verde en la ciudad de Zhengzhou, China, con base en el Análisis Morfológico de los Patrones Espaciales

RESUMEN:

La infraestructura verde es comúnmente considerada una vía efectiva para mantener la seguridad ecológica regional y su método de construcción juega un papel esencial en su funcionalidad. En este estudio se definió el área central de Zhengzhou como la zona de investigación. Los mapas de uso del suelo en el área de estudio se obtuvieron a través de la clasificación supervisada de la información de imágenes Landsat (TM/ETM) en 2007, 2011, 2015 y 2019. La infraestructura verde en el área de estudio se obtuvo con el Análisis Morfológico de los Patrones Espaciales (del inglés Morphological Spatial Pattern Analysis, MSPA) con base en el índice de conectividad del paisaje y la teoría del mapa del paisaje. La conectividad del paisaje en la zona central del área de estudio se clasificó y se evaluó cuantitativamente. Luego se extrajeron y se analizaron los corredores ecológicos potenciales. La investigación sobre el cambio en el patrón de la infraestructura verde con base en el método MSPA, en la conectividad del paisaje y en la teoría de mapas significó un nuevo marco teórico para analizar el cambio de patrón de este tipo de infraestructura. Finalmente se obtuvo la estructura espacial de la infraestructura verde planeada por la administración de la ciudad de Zhengzhou y se propuso una estrategia de optimización de esta red estructural. Los resultados de la investigación pueden ofrecer referencias para la planeación y optimización de redes de infraestructura verde en el área de estudio y tiene una referenciación particular en estos procesos de planeación y construcción en otras áreas geográficas.

Palabras clave: arquitectura del paisaje; Análisis Morfológico de los Patrones Espaciales; infraestructura verde; ciudad de Zhengzhou

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1. Introduction

The rapid development and construction of the cities improve their economic efficiency but lead to aggravated destruction of ecological environments. The city's expansion leads to the fragmentation of ecological networks (Qiu, Chang, & Wang, 2013), and even the retrogressive reduction of ecological networks and the reduction of habitat core areas, which seriously damage the ecological service function of the landscape. The cut-off of ecological corridors leads to a decrease in biological migration channels and affects the development of biodiversity. In a word, the process of urbanization seriously affects the health and integrity of the ecosystem.

Green infrastructure (GI), proposed in the 1990s, was initially separated from eco-green environmental network infrastructure and opposed to other conventional infrastructure (grey infrastructure). GI is a network system that contains a variety of natural and restored ecological and landscape elements, according to the definition of the United States Government Joint Expert Group (Benedict, & McMahon, 2012). So far, its connotation and research scale are constantly enriching. Research on various regional scales by MSPA in China and abroad has been continuously carried out and perfected in recent years. As an example, at the national level, there are studies on GI change assessment for the United States territory and forest fragmentation and connectivity throughout Europe. At the urban level, there are studies about the GI development of Virginia and its surrounding states, the studies on GI of the border between Austria and Hungary, and the studies on the construction of related ecological networks in Sichuan and Chongqing, Jiangsu, and Zhejiang of China (Chen, 2015). On the medium and small scale, there are studies about the spatial and temporal changes of ecological network patterns in Guangzhou, Shenzhen, Nanjing, and some counties in China (Zhu, Ren, & Liu, 2019; Chang et al., 2013; Yu et al., 2016; Byrne, Lo, & Jianjun, 2015).

Zhengzhou, a national central city, is the core city that plays a leading role in the Central Plains Urban Agglomeration. It is rich in natural resources and runs through the Yellow River. However, during its development, urban diseases become increasingly prominent, including the weakening of urban function, and the poor effect of rain and flood caused by habitat fragmentation. The changes and construction of its green infrastructure should be studied to make it a leader in the development and construction of green infrastructure and to drive the green infrastructure construction of other cities, which is of great significance to the formation of green ecological networks of the Central Plains Urban Agglomeration

2. Applicability of MSPA

Introduction to MSPA

MSPA (Morphological Spatial Pattern Analysis), a morphological-based spatial pattern analysis, is initially used by scholars at European Union Joint Research Center (JRC) to study forest fragmentation and species conservation (Ostapowicz, 2008). MSPA is an image processing method to analyze the spatial pattern of raster images based on the principle of binary morphology in mathematical morphology. It can classify image pixels according to the corresponding landscape types by accurately recognizing, measuring, and segmenting the images to distinguish the landscape types and structures. Combining the MSPA with the minimum path analysis, the connectivity among the structural landscape elements and elements can be well identified and analyzed, and the potential ecological corridor can be obtained. The emphasis of ecological network research is shifted to the connectivity level of the ecological source site and ecological corridor, which solves the subjectivity of other research methods and makes the constructed ecological network more scientific.

Ecological correspondence between MSPA and GI

(1) Definition of GI

GI is easily understood as the infrastructure related to green space, like engineering facilities. Its more accurate definition is the network of natural areas, open space with internal connectivity, and possible ancillary engineering facilities. This network has the function and value of a natural ecosystem. It provides natural places for human beings and wildlife, such as habitat, clean water sources, and migration channels, constituting the ecological framework to ensure the sustainable development of the environment, society, and economy. At the micro level, GI refers to the patches and corridors of specifically related engineering facilities or green spaces, such as flood control systems, water purification facilities, a secondary forest, a tree, or even a green roof. In the absence of a specific reference, it emphasizes the connectivity of the whole. Specifically, GI is a multi-level system ranging from the land-wide ecological protection network to the street rainwater garden (Liu et al., 2013). At the regional level, GI supports functions of critical ecosystems constituted by national parks, coastlines, major river corridors, long-distance footpaths, and so on. At the urban or community level, GI forms an open space network consisting of urban parks, recreational areas, farmland, community gardens, street landscapes, private gardens, cemeteries, small water bodies and streams, rooftop gardens, etc.

(2) MSPA and GI

GI is a natural and artificial green space network system composed of "hubs" and "link corridors". MSPA analyzes the geometric characteristics and connectivity of binary images of any scale and type by dividing it into seven categories that do not overlap, so it can also be used to construct GI networks (Wang & Lin, 2017). First, after it is reclassified using the land cover change data, the GI elements are extracted as "foreground" and other non-GI elements as "background". Then, through a series of image processing techniques, the foreground is divided into seven categories that do not overlap (Table 1): The "center" is the "hub" of the GI, and the "bridge" is the "corridor" of the GI. Finally, the GI network is constructed according to the "center" and "bridge" of the MSPA to determine the GI elements and patterns, find the potential "hubs" and "corridors", and realize the interconnected network.

Table 1. Landscape ecology meanings for various MSPA elements

Type of element	Landscape ecology meaning
Core area	Large green patches and distinguishable nonlinear landscape elements in space. It is the «source» of various ecological processes, providing habitat for wildlife, and plays an important role in the protection of biodiversity and the maintenance of urban ecological environment.
Connecting bridge	The channel connecting the adjacent core areas and a narrow zone different from the landscape elements on both sides. It has corridor properties and is a channel for the exchange and flow of energy flow and material flow. It has a direct impact on species mobility and landscape connectivity.
Marginal zone	The transition region between the periphery of the core area and different landscape elements. It has the attributes of landscape boundary in ecology. The adjacent landscape permeates, connects and distinguishes each other through the marginal zone, and has not only characteristics of adjacent landscape but also its own unique components. High heterogeneity.
Branch line	The passage connecting the core area and the peripheral landscape. It also has corridor properties, but its connectivity is generally poor.
Ring zone	The internal passage connecting the same core area. It also has corridor properties, and enhances species diffusion and energy flux within the core area.
Isolated island	Obviously different from the surrounding landscape elements, isolated and broken small patches. The internal species communicate less likely with external species. However, as a small green space in the built area, it plays an important role in the construction of the whole ecological network.
Pore	The transition zone between the core area and its internal construction land. It also has marginal effects, reflecting the degree of species isolation and the possibility of potential gene variation.

3. Research Areas and Research Methods

Research areas

Zhengzhou, a core city of the Central Plains Urban Agglomeration, is in central China. It is in the Yellow River's middle and lower reaches and the Funiu Mountains' northeast wing to the Huanghuai Plain transition zone. The west is high, the east is low, the middle is high, the northeast is low, and the southeast is low. It has a north-temperate continental monsoon climate, over 100 rivers, and 6 municipal districts. According to the latest approved *Zhengzhou Master Planning (2010-2020)*, Zhengzhou central city includes five districts within the administrative area of Zhengzhou City: Zhongyuan District, Jinshui District, Erqi District, Guancheng District, Huiji District. The total area measures 990 square kilometers.

Data source acquisition and preprocessing

This study mainly used the remote sensing image data of Zhengzhou city with the Landsat5\Landsat8 satellite TM/ETM format in 2007, 2011, 2015, and 2019, with 30m precision. First, atmospheric and radiation corrections were conducted, and regions of interest were created using ENVI (Xie, Wang, & Luo, 2020). Then, through the supervision classification, visual correction, and field investigation, the remote sensing images were divided into six categories: woodland, cultivated land, grassland, water area, construction land, and unused land. Finally, based on the Zhengzhou Master Planning and the classification of land use types, the six categories were corrected to form the classification map of land use types in Zhengzhou in the four years.

Research methods

ArcGIS performed mask extraction and re-classification, and the classification map of land use types in Zhengzhou central city was extracted. In graphic data, the four GI elements of woodland, cultivated land, grassland, and water area were extracted as "foreground", and other non-GI elements of construction land and unused land were extracted as "background". And 30m x 30m TIFF binary raster data files were generated and imported to the Guidos Toolbox. Based on the evaluation of landscape connectivity of seven types of landscape elements in Zhengzhou in 2019, the classification of core areas and the extraction of potential ecological corridors were carried out, and the GI planning strategy of Zhengzhou central city was put forward.

4. Changes of GI Spatial and Temporal Pattern of Zhengzhou Central City by MSPA

The data of MSPA landscape type changes in Zhengzhou central city from 2007 to 2019 were obtained. Table 2 shows that the total GI area of Zhengzhou central city was decreasing year by year, which, however, was slowing down. It decreased by 112.167 km^2 from 2007 to 2011, 36.927 km^2 from 2011 to 2015, and 52.074 km^2 from 2015 to 2019. GI decreased slowest from 2011 to 2015 but quickened in recent years. The above results also indirectly showed that the construction land area in Zhengzhou central city has been increasing yearly. Table 3 shows that the core area was dominant in the landscape type. The area of core area decreased from 449.856 km^2 in 2007 to 185.724 km^2 in 2019, the ratio to total GI area decreased from 70.68% in 2007 to 42.69% in 2019, and the ratio to the total area of the central city decreased from 45.44% in 2007 to 18.76% in 2019, meaning a significant decrease. This is because Zhengzhou city constantly expands, and its increasing construction land encroaches on other land. Although the isolated islands are not connected, they can play a stepping-stone role of "ecological island hopping" in constructing ecological networks (Wang, Shen, & Jin, 2019) and are likely to form a connecting bridge or core area with the increase of their area. The area of isolated islands increased from 17.424 km^2 in 2007 to 40.788 km^2 in 2019, the ratio to total GI area increased from 2.73% in 2007 to 9.37% in 2019, and the ratio to the total area of the central city increased from 1.76% in 2007 to 4.12% in 2019, meaning a significant increase. The connecting bridge is vital in constructing ecological networks, such as connecting core areas, material energy exchange, and biological migration. The area of connecting bridge increased from 13.068 km^2 in 2007 to 29.997 km^2 in 2019, the ratio to total GI area increased from 2.06% in 2007 to 6.9% in 2019, and the ratio to the total area of the central city increased from 1.32% in 2007 to 3.03% in 2019. It showed that the construction of ecological corridors and GI connectivity in Zhengzhou's central city were on the rise, promoting the overall optimization of ecological network construction in Zhengzhou. In addition, there was almost no change in the ring zone, and the proportion of the pore area was reduced, indicating that the internal integrity of the core area was enhanced. The proportion of the marginal area increased slightly, indicating that the tiny core area increased and the core area fragmentation increased. An increase in the proportion of the area of the branch line indicated an increase in the green belt between construction land and GI.

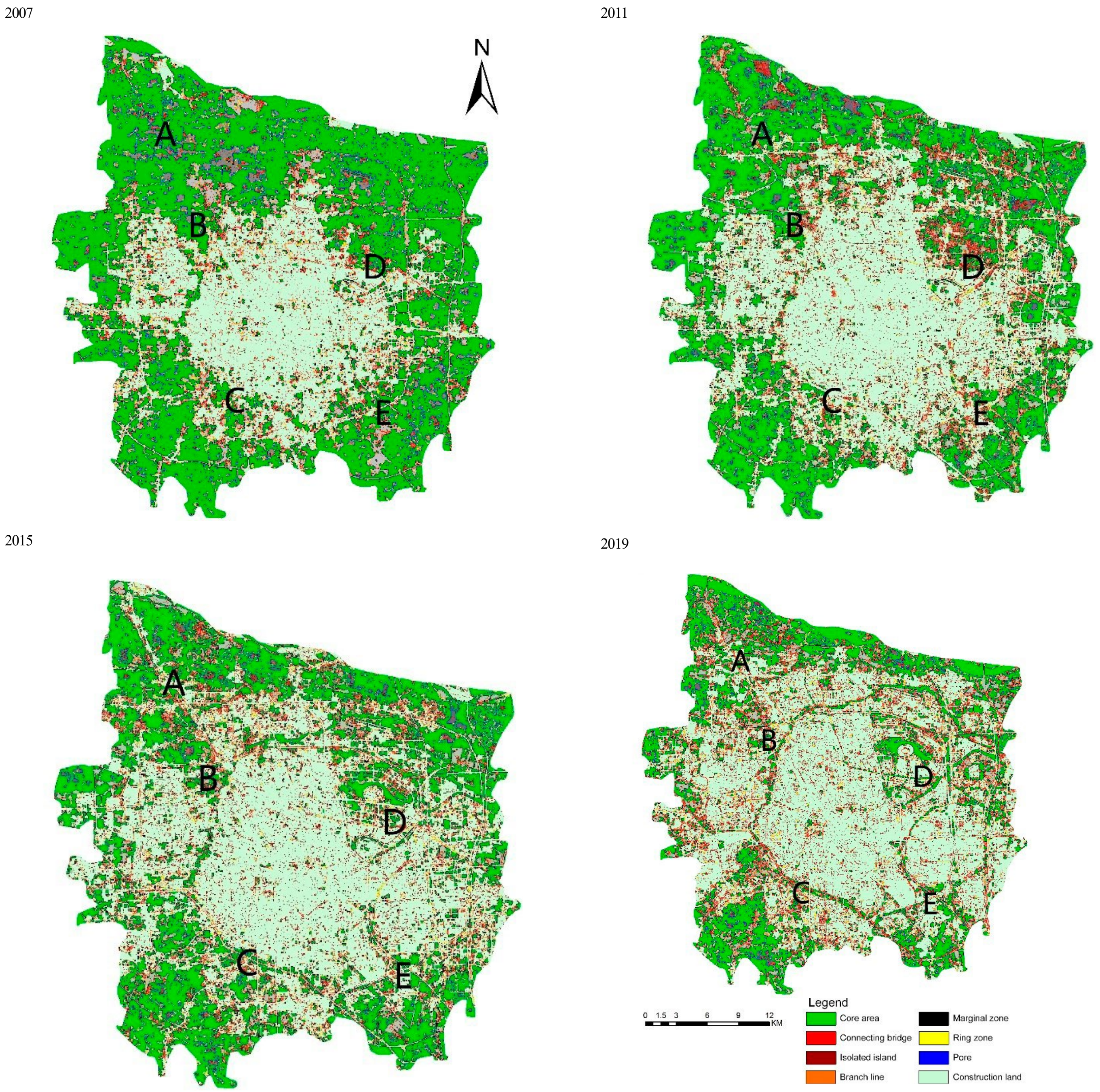
Table 2. The total landscape GI area in Zhengzhou central city from 2007 to 2019 based on MSPA (km²)

Year	Total GI area(km²)
2007	636.372
2011	524.205
2015	487.278
2019	435.204

Table 3. The changes in various landscape types in Zhengzhou central city from 2007 to 2019 based on MSPA

Landscape types	Year	Area(km²)	Ratio to total GI area(%)	Ratio to the total area of central city(%)
Core area	2007	449.856	70.68	45.44
	2011	302.247	57.67	30.53
	2015	254.133	52.14	25.67
	2019	185.724	42.69	18.76
Isolated island	2007	17.424	2.73	1.76
	2011	27.621	5.27	2.79
	2015	32.175	6.61	3.25
	2019	40.788	9.37	4.12
Pore	2007	41.679	6.55	4.21
	2011	27.225	5.19	2.75
	2015	19.8	4.05	2
	2019	13.563	3.11	1.37
Marginal zone	2007	79.299	12.47	8.01
	2011	103.059	19.67	10.41
	2015	113.355	23.27	11.45
	2019	114.048	26.21	11.52
Ring zone	2007	10.494	1.65	1.06
	2011	9.603	1.82	0.97
	2015	9.702	2	0.98
	2019	9.9	2.26	1
Connecting bridge	2007	13.068	2.06	1.32
	2011	23.463	4.47	2.37
	2015	21.681	4.45	2.19
	2019	29.997	6.9	3.03
Branch line	2007	24.552	3.86	2.48
	2011	30.987	5.91	3.13
	2015	36.432	7.48	3.68
	2019	41.184	9.46	4.16

Figure 1 shows that the construction land area in Zhengzhou central city is rapidly expanding, the peripheral core area is gradually swallowed up, the integrity of the core area is poor, the core patch is increasing, and the GI fragmentation is becoming more and more serious. However, depending on the urban ecological construction, some core areas show a trend of converging growth, and the connectivity of some areas is enhanced. The A in Figure 1 is Guxing Town and Guangwu Town in Huiji District, the Yellow River scenic spot, the wetland beach area, and so on. It is mostly rural cultivated land, surrounded by many mountain forests, large forest scenic parks, and the Yellow River Nature Reserve. The urban construction here gradually expanded to the northwest, and plants, schools, and other construction occupied cultivated land. Since the construction of the Yellow River scenic spot railway station in 2015, the railway has split the core area here, and then the landscape fragmentation intensified. The B is Shifu Town and Jalu River of Zhongyuan District of Zhengzhou City, where there are also many cultivated lands and public green spaces such as Shifu Chensha Pool and Zhengzhou Green Valley Quality Culture Park. However, the cultivated land area was reduced due to the construction of numerous residential areas. Still, the core area of landscape along the Jalu River increased. The C is a large number of mountain terraces, as well as Changzhuang Reservoir, Jalu River, South-to-North Water Transfer main trunk canal, and other water bodies. The core area here also has a decreasing trend and fragmentation state, but the process of decreasing is relatively slow. Many water core areas, especially the landscape core areas on both sides of the central trunk canal of the South-to-North Water Transfer Middle Line, are gradually connected. The D is a part of Jinshui District, including the Yellow River Wetland Reserve in the north, Zhengzhou CBD (Central Business District) and Longzi Lake University Park, as well as the Jalu River, Longhu Lake, Dongfeng Canal, Xiong'er River, Weihe River, Longzi Lake, and other waters. There are some cultivated lands along the Yellow River in the north, where the city's expansion to the north is evident, and the landscape core area needs to be fixed. However, the landscape core area of the river region is also gradually connected as a whole. The E is part of the Guancheng District, where some cultivated land is in Nancao Township. The landscape core area is more seriously broken, and the core area of Qilihe River, Chaohe River, and Diehu Lake is well developed.



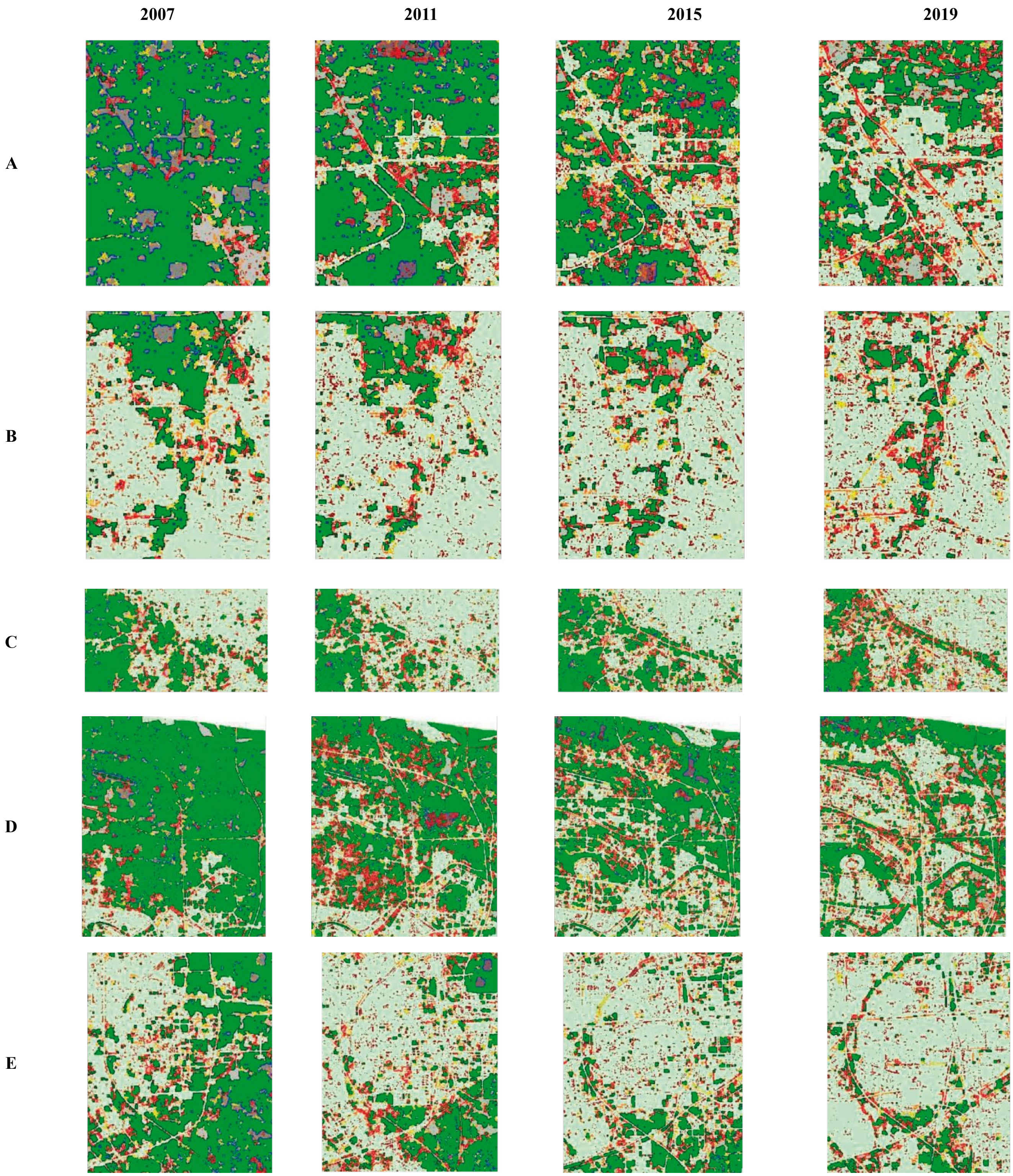


Figure 1. Temporal and spatial variation in green infrastructure of Zhengzhou central city in 2007, 2011, 2015, and 2019 based on MSPA.

5. Classification of Green Infrastructure in Zhengzhou Central City

5.1. Classification of core areas

In this study, the possible connectivity index (PC) was selected to evaluate the landscape connectivity of the core area (Gao, Huang, & Li, 2019) and the calculation formula of PC was as follows:

$$PC = \frac{\sum_{i=j}^{n} \sum_{j=1}^{n} a_i a_j p_{ij}^{*}}{A_L^2} \tag{1}$$

Where "n" is the total number of patches in the landscape, "$p*_{ij}$" is the probability of direct diffusion of species in the patch "i" and patch "j." "a_i" and "a_j" are the areas of the patch "i" and patch "j," respectively. "A_L^2" is the total area of the landscape. Referring to the relevant research, the threshold of patch connectivity distance was set to 500 m, and the connectivity probability was set to 0.5 (Xu et al., 2015). The area of the core area (S) was classified into three levels according to the size of the area (Figure 2): S ≤ 0.2km², 0.2<S<4Km², S ≥ 4Km². The possible connectivity index (PC) of each core area was calculated by the landscape connectivity analysis software Conefor2.6 (Figure 3) and classified into three levels: PC ≤ 0.2, 0.2<PC<4, and PC ≥ 4 (Yu et al., 2016). The core area with a possible connectivity index (PC)≥4 had the highest landscape connectivity, which will be regarded as the most important core area in the regional green infrastructure and classified as the first-level core area. The core area with a possible connectivity index (PC) between 4-0.2 had high landscape connectivity, which will be regarded as the important core area in the regional green infrastructure and classified as the second-level core area. The core area with a possible connectivity index (PC)≤ 0.2 had the lowest landscape connectivity (Figure 4), which will be regarded as the general core area in the regional green infrastructure and classified as the third-level core area. It was concluded that there were 9 first level core areas, including the Yellow River Nature Reserve in the north, the Guxing Town and Guangwu Town in the northwestern Huiji District, the Changzhuang Reservoir, Jalu River, and other Xiliuhu street areas in the southwest. The second level core areas mainly covered the Longhu Lake area in the eastern Jinshui District, including the Jalu River, Longhu Lake, Dongfeng Canal, Xiong'er River, Weihe River, Longzi Lake, and the Tianjian Lake Park and Xushui River in the west, as well as the Nancao Township in the southeast including the Qilihe River, Chaohe River and Diehu Lake. The third level core areas were mostly urban small and medium-sized park green spaces, roads, and river greening areas, multiple and scattered, but most tended to be connected (Figure 5).

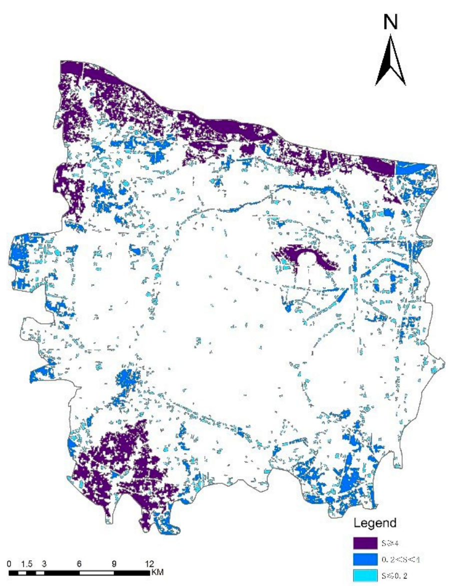


Figure 2. Classification of Green Infrastructure area in the research area

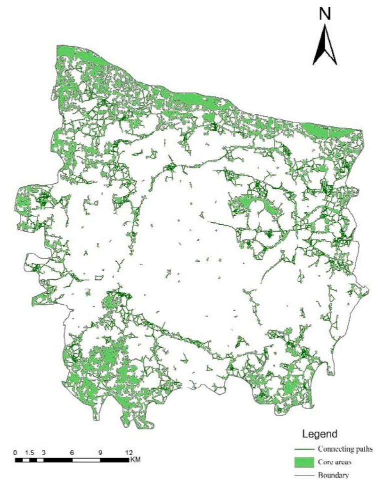


Figure 3. Landscape connectivity analysis in the research area

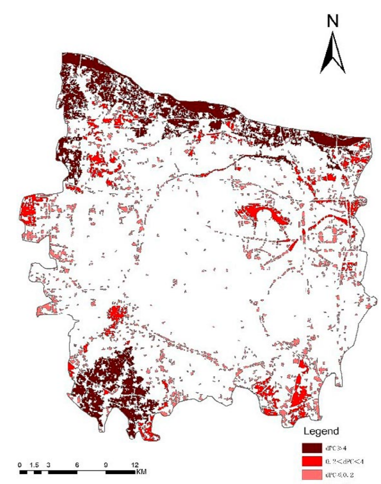


Figure 4. Classification of landscape connectivity in the research area

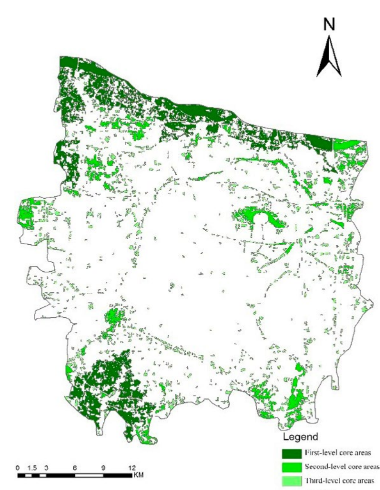


Figure 5. Green Infrastructure classification of the research area

6. Potential Ecological Corridor Extraction of Green Infrastructure in Zhengzhou Central City (Shortest Path Analysis)

The shortest path analysis is the minimum cost distance of individual movement between patches and identifies potential and more reasonable ecological corridors (Yang et al., 2018). According to the classification of GI core area in Zhengzhou, the first level core area is mainly distributed in the north and southwest but rare in the east and southeast. Considering the whole construction of ecological corridor network and the planning of urban green space system in Zhengzhou, a total of 11 core areas including the first level core areas and the second level core areas (Longhu Lake area and Nancao Township in the southeast), which have large area and high connectivity and potential development into the first level core area, were used as ecological source sites. And in the ArcGIS the core areas were transformed into 11 ecological source sites for potential corridor analysis. First, according to the classification map of land use type, the elevation map of Zhengzhou central city and the traffic map of Zhengzhou central city (including railways and all kinds of highways), the resistance of the three types of grid data to the survival and migration of the species was classified from small to large (1-5) by the ArcGIS software, and three kinds of factor resistance base surfaces were formed. Next, based on the different proportional weights of each resistance base surface, the total resistance base surface of Zhengzhou central city was obtained by superposition by grid calculator (Figures 6-9). Then, the minimum cumulative resistance surface of 11 ecological source sites in Zhengzhou central city was generated by using the cost distance module of ArcGIS software (Figure 10). On this basis, the cost distance analysis of 11 ecological source sites was conducted to generate distance raster data and backtracking linked raster data (Figure 11). Finally, according to the distance raster data and backtracking linked raster data, the cost path analysis of 11 ecological source sites was carried out to generate 55 shortest paths, that is, potential ecological corridors (Figure 12).

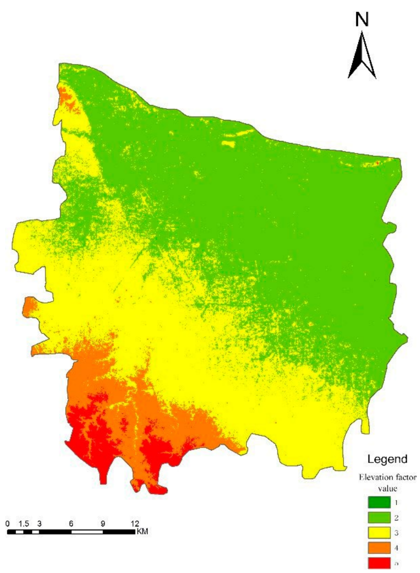


Figure 6 Elevation factor in the research area

Figure 7 Traffic factor resistance in research area

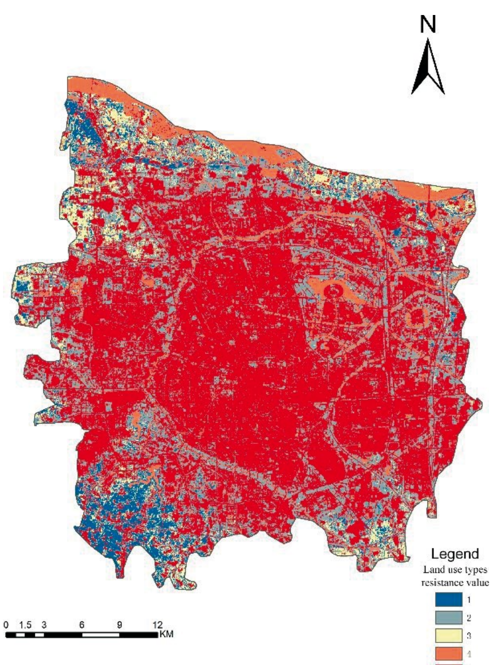


Figure 8 Division of land use types in the research area

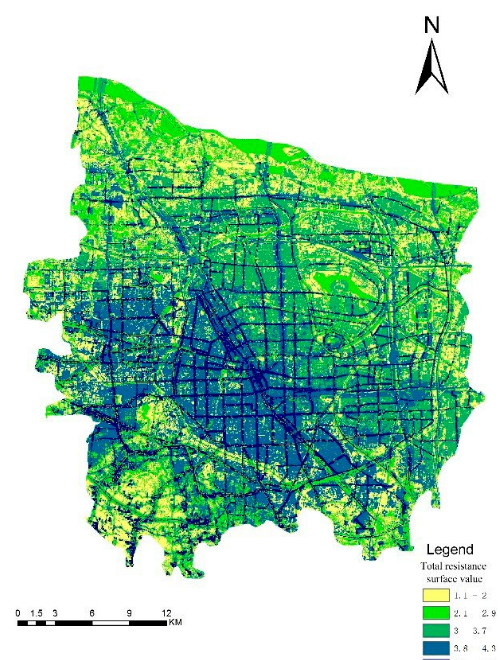


Figure 9 Total resistance surface in the research area

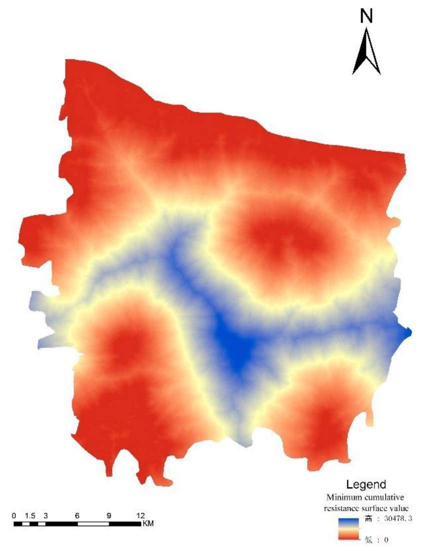


Figure 10 Minimum cumulative resistance surface in the research area

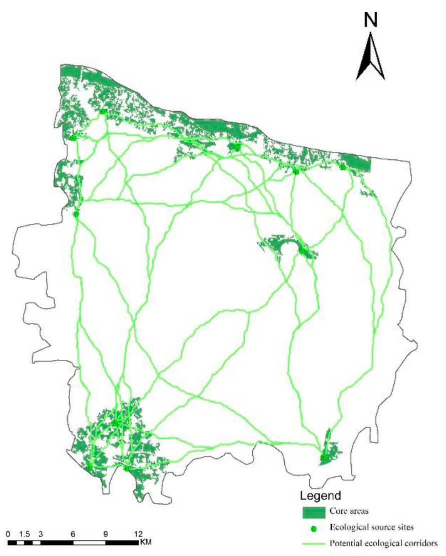


Figure 11 Shortest path analysis of the research area

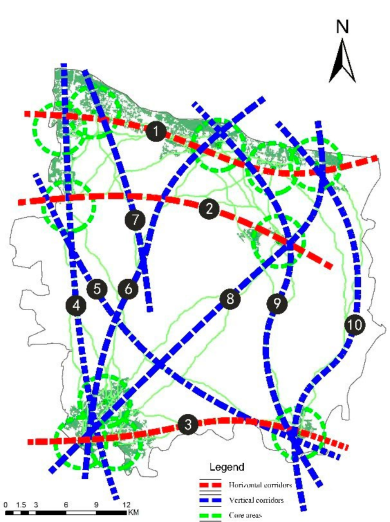


Figure 12 Potential ecological corridors

7. Construction Ideas of Green Infrastructure in Zhengzhou Central city

Protection planning strategy for core areas

The first level core area, which has large area and good connectivity of landscape, plays the most important role in exerting the ecological function of the urban green infrastructure. Therefore, we should focus on strengthening the protection of the first level core area, introducing protection policies, rationally drawing out ecological protection lines, protecting cultivated land and woodland, and strictly prohibiting urban construction land from entering the protection line, strengthening species diversity protection and habitat protection measures, building species diversity habitats, and rationally dividing tourist areas and prohibited tourist areas for areas with tourist functions, so as to reduce human interference and destruction to the growth environment of animals and plants in the protected area.

The second level core area, which is small and has good connectivity of landscape, is mainly distributed in the urban area or surrounded or half-surrounded by construction land. Its ecosystem is unstable and ecological sensitivity is high. Therefore, we should also focus on strengthening protection of the second level core area and enhancing its connectivity with the first level core area, and gradually merge the second level area, which is close to the first level core area, with the first level core area.

The third level core area is mostly small and medium-sized green space in the city and almost connected linear isolated islands formed of narrow riverways, which has the characteristics of connecting corridors and the function of ecological island hopping. In planning, the long and narrow linear isolated islands are further connected in series to play their media role in the green infrastructure, so that they can not only play the ecological function of small core area but also have the connection attribute of ecological corridor, greatly enhancing the integrity of global green infrastructure network.

Protection planning strategy for corridor

Based on the classification of the importance of the core area and the potential ecological corridor extracted, the ecological network structure system of “five core areas, three horizontal corridors and seven vertical corridors” of green infrastructure construction in Zhengzhou central city was put forward (Fig. 12). The “five core areas” are the ecological Core Area along the Yellow River in the North, the Core Area of Guxing Town - Shuangqiao Village, the Core Area of Longhu Lake, the Core Area of Mazhai Town - Houzhai Township and the Core Area of Nancao Township.

The “three horizontal corridors” are:

1. Ecological Corridor Along the Yellow River in the North
2. Longhu Lake Core Area - Weihe River - Jalu River - Yingcai Street - Xiaoshuangqiao Site - Suoxu River - Guxing Town - Shuangqiao Village Core Area
3. Nancao Township Core Area - Jingzhuang Village - Pangzhuang Village - South-to-North Water Transfer River - North Side of Zhihui City - Ziyu Road - Mazhai Town - Houzhai Township Core Area

The “seven vertical corridors” are:

4. Guxing Town - Shuangqiao Village Core Area - Xushui River - Changzhou Road - Jinhua Road - Dongfang Road - Konghe River, Xushui River - Danshui Avenue - Zhengzhou Botanical Garden - Changchun South Road - Mazhai Town - Houzhai Township Core Area
5. Guxing Town - Shuangqiao Core Area - Xushui River - South-to-North Water Transfer River - Nancao Township Core Area
6. Strip Ecological Core Area Along the Yellow River in the North - Jalu River Basin - Mazhai Town- Houzhai Township Core Area
7. Strip Ecological Core Area Along the Yellow River in the North - Madu Trunk Canal - Yao Diandi Community South - Longyi Fourth Street - Longhu Lake Core Area - North-South Canal - Kunli River - Jinshui River - Dihu Lake - Lvcheng Park - Lvcheng Park Southwest - South-to-North Water Transfer River - Baguamiao Community Green Space - Jalu River - Mazhai Town - Houzhai Township Core Area
8. Longhu Lake Core Area - Dongfeng Canal - Xiong’er River - Zhongwang Road - Qilihe River Basin - Zichen Road - Nancao Township Core Area
9. Strip Ecological Core Area Along the Yellow River in the North - Jalu River - Yaoxia Road - Lonzi Lake East Road - Dongqin Street - West of

East Fourth Ring Road - Dongfeng Canal - East of East Fourth Ring Road - Tchaohe River- Die Lake - Nancao Township Core Area

10. (Strip Ecological Core Area Along the Yellow River in the North - Madu Xincun - East of East Fourth Ring Road - Liujiang Hub - East of Beijing, Hong Kong and Macao Expressway - Dongfeng Canal - Putian Township Government Periphery - Chaohe River - Diehu Lake - Nancao Township Core Area

The three horizontal and seven vertical ecological corridors will be given priority to construct, and the green area is widened on both sides of the key sections such as expressway and urban trunk line to build a guiding passage conducive to biological migration. We should focus on strengthening the construction of rivers and surrounding green spaces, strengthening the control of river pollution and the construction of wetland parks, building natural riparian lines, planning and building zonal parks along river channels, and enhancing the ecological attributes of corridors, so as to form a whole green infrastructure ecological network pattern for Zhengzhou central city.

8. Conclusion

This paper extracted, identified, and classified the core area of green infrastructure in Zhengzhou central city by using the MSPA and Conefor landscape connectivity analysis, and extracted the potential ecological corridor of Zhengzhou central city by the minimum consumption path analysis. The results showed that the green infrastructure in Zhengzhou central city was decreasing year by year with the expansion of urban construction, but the degree of fragmentation of the first, second and third level core areas was increasing, but the landscape connectivity was relatively enhanced. The small fragmented core area gradually gathered into the form of ecological corridor, and presented the trend of connectivity. And the ecological corridor composed of water area presented a better trend of connectivity, showing the obvious effect of river ecological construction in Zhengzhou central city. Taking the core area extracted by the MSPA as the ecological source site avoided the subjectivity of the ecological source site extraction. The Conefor analysis can quantify the connectivity of the core area and provide an important basis and data support for the classification of ecological source site and the improvement of connectivity. The minimum consumption path analysis can quantitatively obtain the best path of species migration and provide the basis for scientific planning of ecological corridor. If the green infrastructure can be analyzed according to their different functional types by the MSPA, it will make the optimization of ecological network more detailed. It is hoped that the relevant development scholars will improve this method more scientifically in the future to provide a more scientific and detailed scientific basis for urban ecological construction.

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