

Selection of important ecological source patches base on Green Infrastructure theory: A case study of Wuhan city

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Abstract. Selecting urban ecological patches is of great significance for constructing urban green infrastructure network, protecting urban biodiversity and ecological environment. With the support of GIS technology, a criterion for selecting sources of patches was developed according to existing planning. Then ecological source patches of terrestrial organism, aquatic and amphibious organism were selected in Wuhan city. To increase the connectivity of the ecological patches and achieve greater ecological protection benefits, the green infrastructure networks in Wuhan city were constructed with the minimum path analysis method. Finally, the characteristics of ecological source patches were analyzed with landscape metrics, and ecological protection importance degree of ecological source patches were evaluated comprehensively. The results showed that there were 23 important ecological source patches in Wuhan city, among which Sushan Temple Forest Patch, Lu Lake and Shangshe Lake Wetland Patch were the most important in all kinds of patches for ecological protection. This study can provide a scientific basis for the preservation of urban ecological space, the delineation of natural conservation areas and the protection of biological diversity.

1. Introduction

Urban ecological source patches, one of the important indexes to measure the sustainable development of city, is an important component of urban ecological system. It is very important for environmental protection and ecological restoration. However, in recent years, the rapid development of the city has brought a series of negative impacts on its ecological environment. Forest, water and wetland patches have shrunk, and the edges of these patches have been eroded. Ecologists and environmentalists found that by increasing the connection among ecological patches was able to protect patches from being eroded. So they put forward green infrastructure, which consists of ecological patches and the link corridors between them. Foreign scholars have made mass of study in both theoretical and applied researches on ecological patches and green infrastructure. Pantoula Nikolakaki (2004) presented a method that addressed the problem of site-selection for habitat creation. Konstantinos Tzoulas (2007) through an interdisciplinary literature reviewed the concepts of Green Infrastructure, ecosystem health. Ted Weber (2006) presented a case about the green infrastructure assessment in Maryland, etc.^[1-3]. Although China's research on the ecological environment lags behind abroad, the domestic scholars have already carried out some explorations. XU Wenwen (2012) recognized the important ecological nodes in Nanjing. WU Jiansheng (2013) constructed a method which can select ecological security



pattern source patches according to the connectivity of patch and habitat quality. Wang Zishu (2009) demonstrated an approach to identify and build important green infrastructure in the form of quantitative selection and model analysis^[4-6]. As one of the components of green infrastructure, ecological patches are the basis of defining urban reserved space, constructing ecological network and green infrastructure. Selecting important ecological patches is of great importance to the construction of urban green infrastructure.

Because of the shortage of urban land in Wuhan city, it is not suitable for large-scale ecological construction. Therefore, it is significant to select important ecological patches based on existing ecological resources for constructing urban green infrastructure networks. It can be useful to reserve ecological space and protect urban ecological environment. In this paper, under the support of GIS technology, we selected ecological source patches in Wuhan city based on the existing planning and related documentation. Then we constructed a network of green infrastructure to improve the connection between ecological source patches. Finally, we measured the ecological protection importance of ecological source patches with landscape metrics. Some environmental protection policies can be formulated by environmental protection environmentalists according to our study, which may help to protect biodiversity and satisfy present and future open space needs.

2. Study area

As the capital of Hubei Province, Wuhan city is the largest megacity in central China and in the middle reaches of Yangtze River (29°58′–31°22′N, 113°41′–115°05′E). The city contains 13 districts, which cover approximately 8494.41km². There are a large number of lakes and rivers in Wuhan city, and the area of various waters is 2036 km². It is rich in wetland resources and owns 5 wetland reserves that at the municipal level and above. As of 2016, the city's forest coverage rate reached 22.88%.

3. Materials and methods

3.1. Data source

We used the remote sensing imagery of Landsat 7 ETM SCL-off data from July 29, 2015 in Wuhan city, digital elevation model data with 30 meters resolution, administrative region vector map of Wuhan city, road traffic map of Wuhan in 2015 and atlas of Wuhan greenway system construction plan 2012-2020 as our spatial data. Ecological data about patches comes from catalogue of "Functional Zoning (Level 1) of Hubei Province", "A list of nature reserves in Hubei Province", and so on. Our data was acquired from Geospatial Data Cloud, Advanced Space borne Thermal Emission and Reflection Radio meter Global Digital Elevation Model (<http://gdem.ersdac.jspacesystems.or.jp/>), "Atlas of Hubei provincial highway network, 2015 Edition", Wuhan Land Resources and Planning Bureau, Wuhan Environmental Protection Bureau.

3.2. Ecological source patches selection

As we know, ecological source patches are native species habitats and the sources of species diffusion, and native species can be divided into terrestrial organisms, aquatic and amphibious organisms. We took Woodland, water and green spaces near water as the ecological source patches in this paper, which can represent the habitats of terrestrial organisms, aquatic and amphibious organisms respectively.

Firstly, by manual interpretation from remote sensing data of Landsat7 in 2015, we created a land use map of Wuhan city, which include woodland, farmland, construction land, water and unused land. We chose woodland and waters as preliminary screening results of ecological patches from this map. Secondly, because larger patches can accommodate more species and individuals, according to this characteristic of ecological patches, an area threshold was used as a parameter to select appropriate ecological source patches. Finally, considering the rapid development and land shortage of Wuhan city, it is not suitable to newly construct large-scale ecological source patches. However, ecological source patches recognized by some researchers using sensitivity analysis or ecological security pattern

evaluation were large-scale. So it is more reasonable to construct ecological source patches according to existing planning and those source patches we've chosen in relevant document. Because the wetland couldn't be recognized from the land use map we created, we constructed wetland based on existing planning atlas. Ultimately, our ecological source patches included woodland ecological source patches, water and wetland ecological source patches.

3.3. Green infrastructure networks construction

Based on the above methods, the woodland ecological source patches, water and wetland ecological source patches were selected as green infrastructure elements of Wuhan city. The green infrastructure link corridors between source patches of Wuhan city were constructed by using minimum cumulative resistance model [7-8]. Organisms need to overcome a certain resistance to achieve the migration of species. The minimum cumulative resistance is the minimum cost required for the migration. And different natural conditions and human interference intensity have different effects on landscape resistance values. In this paper, the land use type, elevation, slope, NDVI index and the distance to road are chosen as landscape resistance factors. By analyzing the influence of resistance factors on the resistance in different landscape processes, resistance coefficients were determined (Table.1) [9-11]. The resistance planes were constructed by ArcGIS10.1. And then the potential paths with minimum depletion between ecological source patches were determined by using the minimum cost path method. They are able to connect the source patches, and avoid all kinds of external interference. Finally the network structure with the highest ecological benefit was selected as the green infrastructure network structure of Wuhan city.

3.4. Ecological source patches importance evaluation

Landscape metrics reflect the shape, composition and configuration of patches. They are able to reveal the important degree of ecological source patches. Therefore, patch area (CA), patch shape index (SHAPE) and the ratio of the useful landscape type area to patch area (Ratio) were selected as the landscape metrics in this paper. CA reflects patch size. SHAPE is the ratio of the perimeter of the patch to the perimeter of the round or square patch, which is able to measure the complexity of patches' shape. Higher Ratio means the ecological plaque can provide more favorable landscape types for organisms surviving and migrating. Finally, we comprehensively evaluated the importance of ecological patches with equal weights of the three indexes.

Table 1. Biotic resistance assignment table in Wuhan city

Resistance factors		Resistance coefficients				
Score		10	30	50	80	100
Elevation	Nature breaks method	-141~34	34~87	87~193	193~358	358~787
Slope		<7	7~15	15~25	25~35	>35
NDVI index		>0.4	(0.3,0.4]	(0.2,0.3]	(0.1,0.2]	<=0.1
land use type	Terrestrial organism	Woodland	Farmland	Unused land	Urban land	Water & wetland
	Aquatic & amphibious organism	Water & wetland	Unused land	Farmland	Urban land	Woodland
Distance to road		>1000m	800m	500m	200m	0m

4. Results and analysis

4.1. Ecological source patches selection

By the above-mentioned methods, 12 patches of woodland source patches and 11 water and wetland source patches in Wuhan city were selected. Their area were about 1624.13km², accounting for 19.12% of the study area. Most of the woodland source patches were located in mountain of forest parks or scenic spot, like Maan Mountain Forest Park and Mulan mountain scenic spot. Large water and wetland source patches were located in Jiangxia district of Wuhan city, including Liangzi Lake, Lu Lake and Shangshehu wetland, and Tangxun Lake (Table 2 & Figure.1).

The total length of connection corridors in Wuhan city green infrastructure networks reached 9971.74km. We constructed 66 terrestrial biological migration link corridors, whose length is 5252.94km. We also constructed 55 aquatic and the amphibious migration link corridors, which is about 4718.80km (Figure.2). Through them the species are able to realize migration among the ecological source patches. These link corridors have played an important role in protecting biodiversity and maintaining the stability of ecological source patches.

Table 2. Ecological patch location statement

Patch type	Patch number	Patch location	Patch type	Patch number	Patch location
Woodland	a1	Near the Mulan ancient gate scenic spot	Water & wetland	b1	Mulan Lake
	a2	The Mu Lan Mountain		b2	Wu Lake wetland
	a3	Near the Wu Temple Reservoir		b3	Zhangdu Lake
	a4	Maan Mountain Forest Park		b4	Yanxi Lake
	a5	Longquan mountain, ErLong mountain, Lantau mountain		b5	East Lake
	a6	Bafen mountain, biandan mountain		b6	Tangxun Lake
	a7	Hanlin mountain		b7	Liangzi Lake Wetland
	a8	Leopard Hole		b8	Lu Lake and Shangshe Lake wetland
	a9	Jiuzhen Mountain Forest Park		b9	Chen Lake wetland
	a10	Songyang Mountain Forest Park		b10	Suozhi Long River
	a11	Sushan Temple Forest Park		b11	Houguan Lake
	a12	Shuangfeng Mountain			

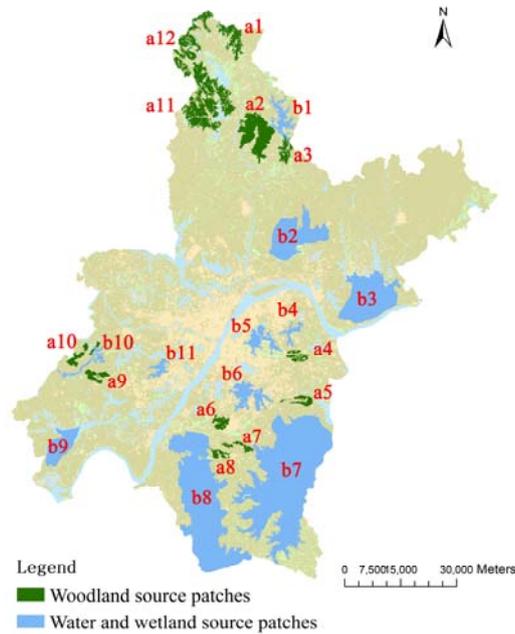
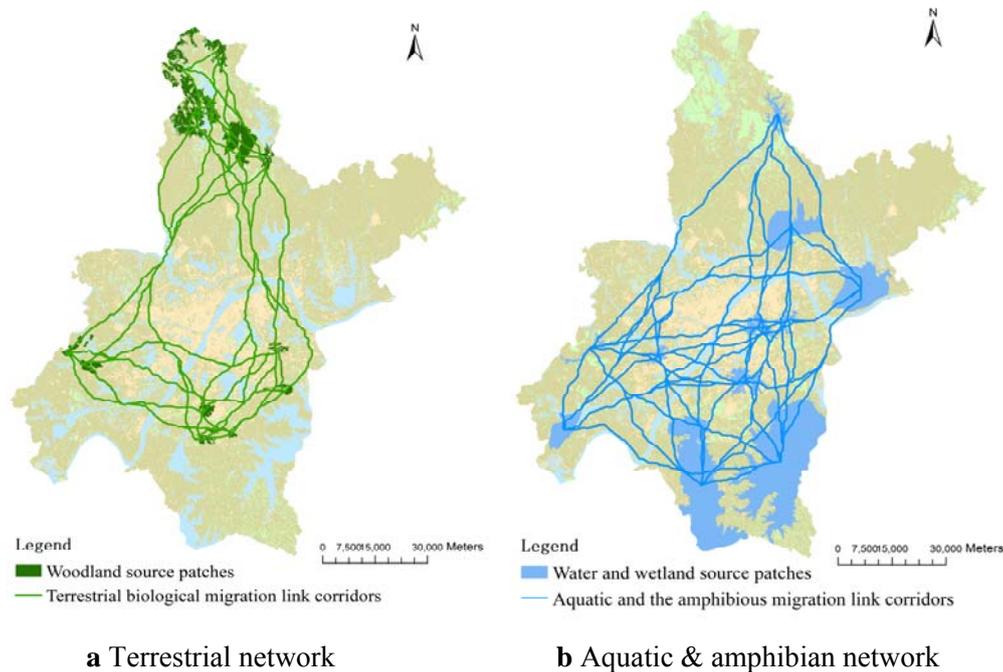


Figure 1. Wuhan ecological source patches



a Terrestrial network

b Aquatic & amphibian network

Figure 2. Wuhan green infrastructure networks

4.2. Ecological source patches importance evaluation

According to comprehensive evaluation of the importance of patch protection, the top 3 woodland source patches were: woodland source patches located in Su Shan Temple Forest Park, Shuangfeng Mountain and Mulan Mountain. While the top 3 water and wetland source patches were: Lu Lake and Shangshe Lake wetland patch, Liangzi Lake Wetland patch and Tangxun Lake patch.

The biggest CA woodland, water and wetland source patch were found respectively near Sushan Temple Forest Park and in Liangzi Lake. The lowest SHAPE woodland, water and wetland source patch were found in Leopard Hole, Lu Lake and Shangshe Lake wetland, and their SHAPE value reached 1.81 and 1.55. Their shapes are regular and edges are not easily eroded. Ratios of nearly all ecological source patches reached more than 75%, some even up to 100%, which means that these source patches we selected are beneficial for migration (Figure. 3).

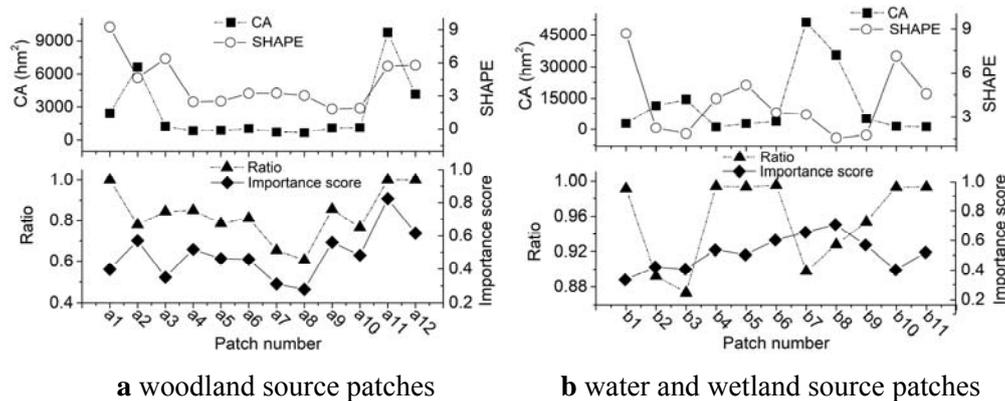


Figure 3. Evaluation results of ecological source patches importance

5. Conclusion

Based on the GIS software platform, we uses spatial data (land use classification map and Planning Atlas) and ecological data to select the woodland ecological source patches, water and wetland ecological source patches of Wuhan city. By using the least resistance model, the green infrastructure networks of Wuhan city were constructed to connect the ecological patches. Finally, the ecological importance degree of the source patches was evaluated by 3 landscape metrics: the patch area, the shape index, the ratio of useful landscape type area to total patch area.

There are 12 woodland source patches in Wuhan city. The comprehensive evaluation score and patch area simultaneously showed that the most important woodland patch was in Sushan Temple Forest Park. 11 water and wetland ecological source patches were selected. Because of the second size, the most regular shape and high Ratio, Lu Lake and Shangshe Lake source patch became the most important water and wetland patch. 121 network connection corridors (66 terrestrial migratory corridors, 55 aquatic and amphibian migratory corridors) were constructed in Wuhan city green infrastructure network, which connected ecological source patches to each other.

Our research provides an important contribution to protect the ecological source patches, coordinate urban land expansion and land conservation, to maintain urban ecosystem services and ecological quality in human settlements.

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