A Methodological Study of Biotope Mapping in Urban Areas: Case of Xuanwu District, Nanjing City, China

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Abstract: This study aims to understand the characteristics of urban biotopes in the context of Xuanwu District (Nanjing, China), in order to elaborate a biotope mapping system and environmental assessment database for the urban landscape management. Basic data include an aerial photograph, a topographic map, a land use map and a compartment map associated with the field survey. Arc GIS 10.2 was used to carry out biotope mapping and biotope value assessment. Both the comprehensive biotope mapping method and the typical sampling method were used for multi-scale comparison. On the basis of the above research, we aim to put forward the ecological conservation strategy for sustainable planning and the recovery of equilibrium in the city.

Keywords: Biotope mapping, biotope value assessment, GIS, urban landscape management

1 Introduction

A "Biotope" is defined as a living place which can be distinguished from the physical environment around it by features like land shape, structure and even living communities within it, so it has a certain size and homogenous characteristic (SUKOPP 1988). Urban biotope mapping, which divides the urban biotopes and records its spatial data and attributive data, is formed by urban architectural features, vegetation and plant, bodies of water, human activities and other factors. The entire urban landscape is composed of an overall structure of biotopes in which each biotope possesses an ecological function. It is therefore required to observe and improve the ecological value of the entire landscape from an overall perspective (WERNER 1999). Biotope mapping can be used not only for nature conservation tasks, but also for urban and regional planning, environmental analysis and environmental impact assessments (BERLIN SENATE DEPARTMENT FOR URBAN DEVELOPMENT 2006).

First originated in the 1970s in Germany, the biotope mapping method has been utilised in an increasing number of countries including the UK (NATURE CONSERVANCY COUNCIL 2007), Sweden (LÖFVENHAFT 2002), Turkey (FREEMAN 2003, MANSUROGLU et al. 2006), Japan (MULLER 1998, OSAWA et al. 2004), South Korea (HONG et al. 2005) and New Zealand (FREEMAN & BUCK 2003). Following the technology development, digital methods like GIS, Colour infrared aerial photography technology, satellite remote sensing technology, and aerial hyperspectral imaging technology have been used in the mapping method (QIU et al. 2010), which greatly improve the accuracy and efficiency of mapping.

Although the biotopes of ecological importance in urban environments in China are under great pressure because of negative factors such as urbanization, air pollution and human disturbance, domestic research on urban biotope mapping is still in its infancy, only a small number of individual scholars have carried out relevant research studies in localized areas: such as the peri-urban areas in Xi'an (ZHAO et al. 2007) and Huaqiao new city in Kunshan

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City (ZHAO 2012). The comprehensive biotope method and selective biotope method are jointly used in these pieces of research, but in terms of accuracy of biotope classification and comprehensive degrees, there still exists a certain gap among the western developed countries. No consensus has been reached on a suitable biotope mapping classification framework for urban environment in China. Research has so far only focused on specific pockets within wider urban areas, and thus fails to present a comprehensive overall picture. There is also little research about how to apply the biotope mapping results into landscape and urban planning processes. The aim of this study is to address these shortcomings. On the one hand, it aims at elaborating a biotope classification system in the Chinese context while absorbing the merits of advanced countries. On the other, it hopes to create a comprehensive biotope mapping and biotope value assessment for sustainable urban management and ecosystem equilibrium. The Xuanwu District of Nanjing city, with an area of 74.78 km^2, which consists of a complex landscape pattern of "mountain, lake, city, forest" is examined in this research.

2 Material and Methodology

This section describes the information resources needed for the research as well as a five-step methodology used for biotope mapping and biotope value assessment.

2.1 Information Resources

In this study the biotope sites were determined by the interpretation of panchromatic aerial photographs and existing compartment maps, assisted with field verifications. This was to improve biotope distribution reliability. The following sources in Table 1 were used for the collection of primary data:

Table 1: Basic data for biotope mapping

Number	Map and Land Classification	Authors	Time
1	Land Use Map of Xuanwu District	Nanjing urban planning bureau	2010
2	Topographic Map of Xuanwu District (1:5000)		2012
3	Regulatory detailed planning of Nanjing computer aided drawing specifications and results archived data standards (2013-2020)		2012
4	Nanjing urban land classification and code standard		2013
5	Forestry/Compartment Maps of Purple Mountain	Nanjing forestry bureau	2005
6	The urban land classification and planning construction land standard GB50137-2011	Ministry of housing and urban-rural development	2011
7	Green Space Planning Framework		2002
8	Satellite image	Google map	2015

3, 4, 6 and 7 in the above table were used for coding purpose i. e. the codes in these standards are used to clarify the further classification and colour code of biotope types.

2.2 Methodology

The biotope mapping model comprised five steps of strategic selection while following the tempo-spatial lines: preparing information resources and field survey; the building of the urban biotope classification system; the establishment of the urban biotope data base of study area; the evaluation of the biotopes relating to the value of nature conservation; and the design of the biotope chain strategy for landscape and urban planning.

The biotope mapping was carried out in two scales: the whole area followed by the typical sample area. Two commonly used methods are the comprehensive biotope mapping method and sample biotope mapping method. In this paper, due to the limited space, only the comprehensive mapping results are introduced. Through the field survey and map interpretation, the biotope research was recorded and translated in CAD database and GIS Platform. Then, the method produced a value assessment of biodiversity including criterions like permeability of land, structure of vegetation, canopy coverage, species richness, and water revetment. The future plans of the Nanjing city will be continuously updated according to the renewal of the biotope value assessment.

2.2.1 Biotope Classification System

According to the comparison of biotope classification in 14 cities in the following countries: Germany, the UK, Sweden, Turkey, New Zealand, Japan, Korea, China and land use regulation in Nanjing (number 3, 4, 6 and 7 in Table 1), we divided the urban biotope mapping system of Nanjing into 6 first level classifications, 21 second level classifications, 85 third level classifications, and 18 fourth level classifications. Each category had the corresponding coding system and colour code [partially in accordance with *Regulatory detailed planning of Nanjing computer aided drawing specifications and results archived data standards (2013-2020), Nanjing Urban Planning Bureau*]. In consideration of the actual site condition, the work content and the depth of the different requirements, the field research will use the relevant categories accordingly. The four levels of biotopes were further divided according to the criterions in Table 2.

Table 2: Biotope classification criterion in Xuanwu District

Level	Criterion
1st level	**core area**: construction area, green area and water area **peripheral area**: forest land, agricultural land and wasteland
2nd and 3rd level	**core area**: refer to code and classification in number 3 of Table 1. Mainly including residential areas, public management and public service, business service facilities, industrial area, logistic storage area, special area, transportation, public facility, amenity open space, nursery, green buffer, other green space, flowing water and still water. **peripheral area**: refer to code and classification in number 5 and 7 of Table 1. Mainly including man-made forest, natural forest, plough, orchard, meadow, agriculture facility, unused land and wasteland
4th level	**construction area and green area**: water and vegetation communities; **watershed**: hardness and softness of revetments, abundance and infertility of vegetation; **forest areas**: species richness and tree canopy density; **wasteland and agriculture land**: no further classification

2.2.2 Comprehensive Biotope Mapping

After setting up the classification system in the research area, the next phase was to establish biotope database of Xuanwu District. This was done by overlapping careful field work to clarify biotope conditions, the land-use map (1), a satellite photo (8) and the topographic map (2) (see number in Table 1 above). These data will be first documented as a preliminary database in AutoCAD software, and later turned into Arc GIS 10.2 platform for analysis. Different biotope types were marked with corresponding layers and legends, which were reflected with the code and colour mentioned in the classification system (3, 4, 6 and 7). The comprehensive biotope mapping (see Fig.1) also served as a foundational map for analysis of biotope distributions in different land use and the detailed information of specific biotope use. The data and graph will be updated as biotope information changes.

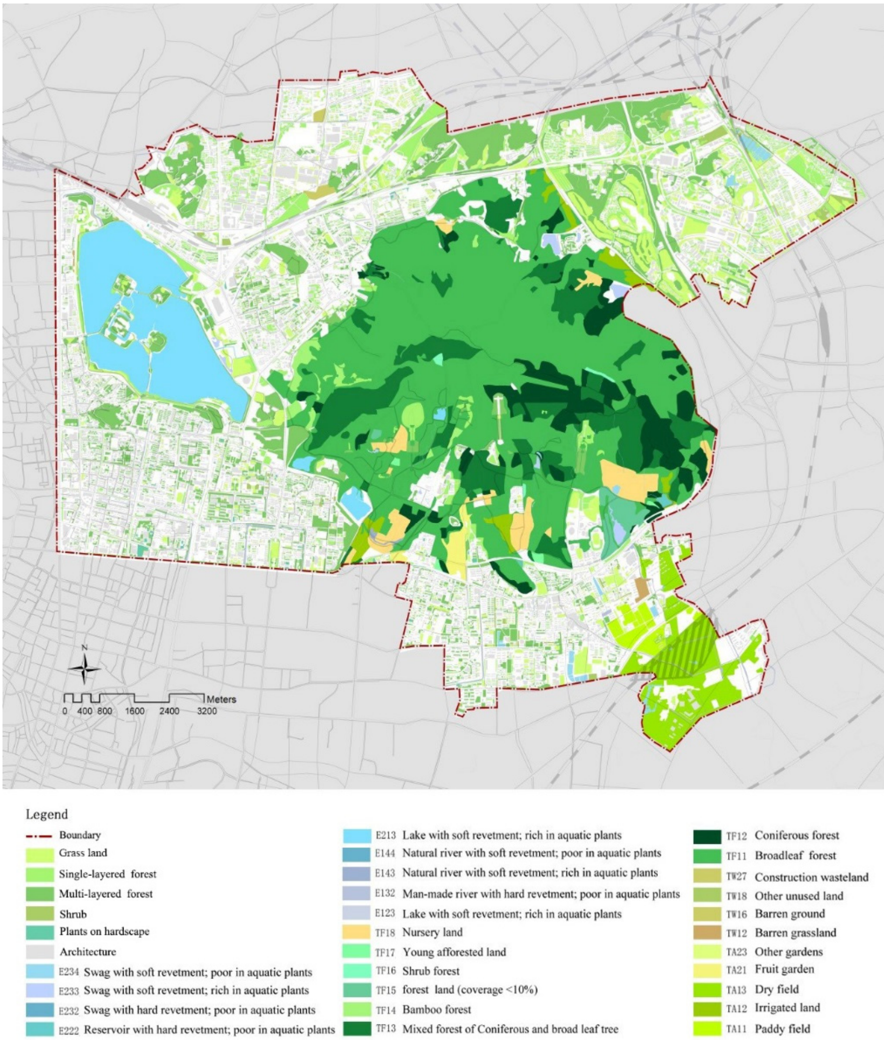

Fig. 1: Comprehensive biotope mapping of Xuanwu District

2.2.3 Biotope Value Assessment

Ecological factors of the fourth level biotopes were mainly assessed through the following five parameters. They were permeability of land, structure of vegetation, canopy coverage, species richness, and water revetment. This is because these indexes can not only reflect the differences in vegetation survey, but also provide a scientific basis for carrying out statistical analysis and quantitative evaluation.

The evaluation standard was classified into 6 values in accordance with the equivalence principle. The score of “0-5” represented the value of ecological dominance of ‘none’, ‘low average’, ‘poor’, ‘high average’, ‘good’ and ‘very good’ (see Table 3). In response, the weight of biotope was the result of biotope value divided by 1.

Table 3: Fourth level biotope classification (showing Biotope value, Weight, Abbr. Code)

Level 4	Number	The fourth biotope unit	Biotope Value	Weight	Abbr. Code
Green space	1	Architecture	0	0	A
	2	Hardscape	0	0	H
	3	Multi-layer Tree	5	1	M
	4	Single-layer Tree	4	0.8	S
	5	Shrub	3	0.6	B
	6	Green place on hardscape	1	0.2	G
	7	Grassland	2	0.4	C
Watershed	1	Hard revetment; rich in aquatic plants	3	0.6	HR
	2	Hard revetment; poor in aquatic plants	2	0.4	HP
	3	Soft revetment; rich in aquatic plants	5	1	SR
	4	Soft revetment; poor in aquatic plants	4	0.8	SP
Forestland	1	Single-layer forest with high coverage	4	0.8	SH
	2	Single-layer forest with low coverage	3	0.6	SL
	3	Multi-layer tree with high coverage	5	1	MH
	4	Multi-layer tree with low coverage	4	0.8	ML
Farmland	1	Plough	2	0.4	TA1
	2	Orchard	4	0.8	TA2
	3	Meadow	2	0.4	TA3

The Biotope value assessment (BVA) was calculated from the ratio of the parts of areas of a site that have a positive effect on the ecosystem or the biotope development to the total area of the site. Each site was defined by the boundary of different types of land uses under the governmental regulatory planning (see Fig. 4).

$$\mathrm{BVA}=\frac{\text{Ecologically Effective Area}}{\text{Total Land Use}}$$

Specific calculations could be represented in the following format, we referred to the Area code and weight of each factor in Table 3 for calculation.

Area (Weighted Greenspace) =
Area(M)*1+Area(S)*0.8+Area(B)*0.6+Area(C)*0.4+Area(H)*0.2
Area (Weighted Forestland) = Area(MH)*1+Area(ML)*0.8+Area(SH)*0.8+Area(SL)*0.6
Area (Weighted Watersheds) = Area(SR)*1+Area(SP)*0.8+Area(HR)*0.6+Area(HP)*0.2
Area (Weighted Farmland) = Area (TA1) *0.4+Area(TA2) *0.8+Area(TA3)*0.4

$$\text{BVA}=\frac{\text{Weighted Area (Greenspace + Watersheds + Farmland + Forestland)}}{\text{Total Land Use}}$$

3 Results and Discussion

3.1 Analysis of Area Statistics

Through the mapping of the whole area of Xuanwu District, the characteristics of the four-level biotopes were studied and summarized. City forest landscape occupied the dominant urban landscape pattern. The main near-natural and semi-forest landscape patches distributed in the Purple Mountain area, and they were more often in the form of multi-layered trees. The types of natural forest belts were concentrated in the river and lake areas, as well as in patches of urban parks. Therefore, the formation, spatial distribution and types of urban forest landscape were closely related to the natural geographical environment.

Fig. 2 gives the results from assessing vegetation spread in construction areas, forestlands, wastelands and farmlands. Through the analysis of the fourth-level classification index of the biotope units; architecture, grassland, hard landscape, shrub, single-layer forest and multi-layer forest, were analysed according to different properties of land types (third classification indexes of biotope units). In general, in the construction area (including A. Public management and public service; B. Business service facilities; H. Military areas; M. Industrial area; R. Residential; U. Public facility; W. Logistic storage area), green land (G), forest area (TF) and wasteland (TW), the covering area of multi-layer tree was the largest, accounting for 64 %; Followed by architecture (17 %), single-layer tree (12 %), grassland (6 %), and shrub (1 %). Hard landscape occupied the smallest proportion (A value of less than 1 % is recorded as 0 %. Similarly hereinafter).

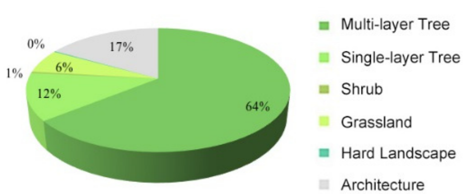

Fig. 2: Biotope distribution in construction areas, woodlands, wastelands and farmlands

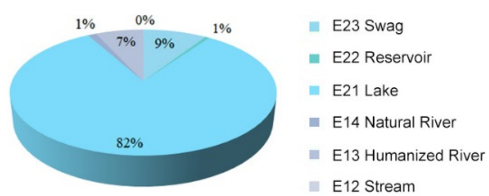

Fig. 3: Biotope distribution in watersheds

We used a separate coding system for the biotope of water bodies. Since it is hard to judge the property ownership of different types of water bodies, for the convenience of calculation, we regarded them as dependent natural elements in the research area. The largest biotope of watershed in Xuanwu District was E21 Lake (see Fig.3), which covered an area of 379.8 ha, accounting for 82.1 % of the total water storage, followed by E23 swag (9.2 %), E13 man-made river (6.9 %), and E14 natural river (1.2 %). The least amount of water was E12 stream segmented in the purple mountain.

3.2 Analysis of Biotope Value Assessment

By attributing the overall grid codes of biotope value assessment (BVA) calculated in section 2.2.3 to land-use map (No.1 in Table 1), which were source derived from the local planning bureau and redrawn in the GIS platform, we could highlight the difference of the biotope value. For representation in the map, the total point count (biotope value) ascertained for each biotope type was broken down into nine biotope value classes. A biotope value (BV) of 0 corresponded to land with a small conflict potential; the scale went up to BV Class 9, with an extremely high conflict potential.

It can be seen from Fig.4 and Fig.5 that, except for the two large landscape parcels − Purple Mountain and Xuanwu Lake, the majority of biotopes in Xuanwu District were found to be sensitive. The overall biotope value tendency was relatively high in the north-east of the Xuanwu District, where high quality residential areas and recreational areas were more often distributed. The residential land and golf course of the north-east side of the mountain were also of high value. The third highest was the northern purple mountain and Xuanwu Lake area. Some of the less developed areas in the northern basalt area also maintained high ecological value. Areas with the lowest biotope value lied in highly urbanized areas in the south-west of the district, industrial area in the northern part, as well as new-emerging areas to the south of purple mountain.

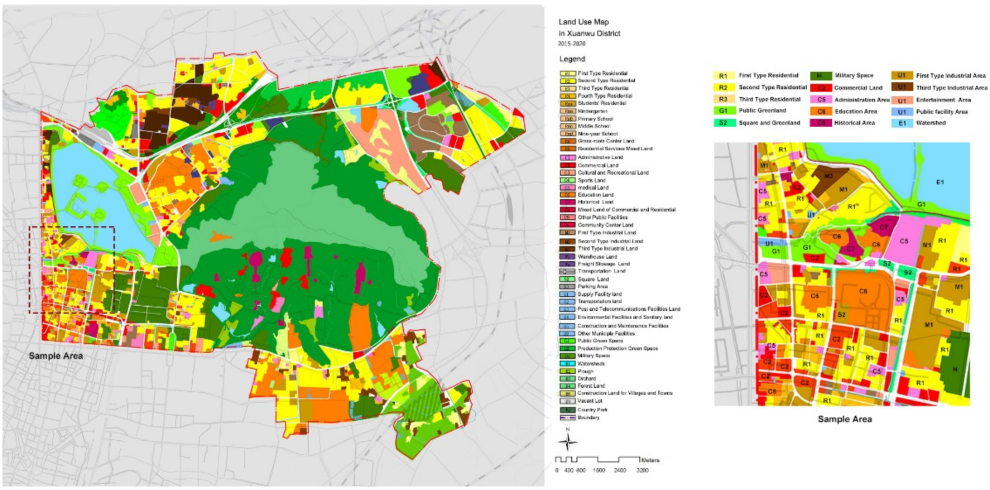

Fig. 4: Land use map

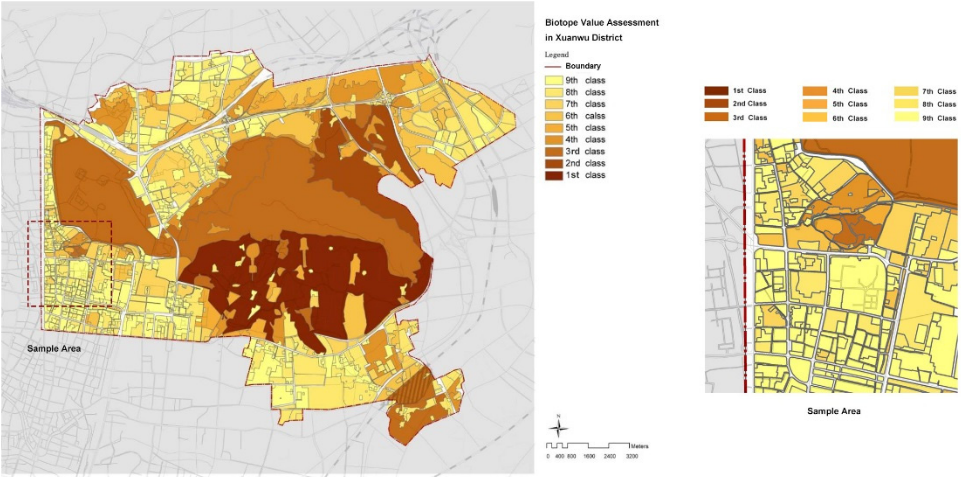

Fig. 5: Biotope value assessment

4 Conclusion and Outlook

The urban biotope mapping is an inter-discipline comprehensive work in urban area, which provides a new data source for the urban ecological construction and researches. By analysing biotope types and carrying out conservation value assessment in study areas, we hope to provide a platform for sustainable planning and the recovery of equilibrium in the city and the region.

We expect in the following research that on the one hand, the detection of biotope units can be combined with more efficient software and hardware technology, so the biotope mapping methods of Xuanwu District will be refined, thus functioning as a good example for other districts in the city. Also, considering the difference between city scale and city environment complexity, we hope to establish a more comprehensive and systematic urban biotope network. On the other hand, we aim to make a good combination of research results with the principle of landscape ecological planning, urban planning principle and other scientific principles, to provide a basis and guidance for an urban and rural green space system planning method in the new historical period, and to make the urban planning and management develop in a more refined direction.

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