Ecological Infrastructure First: A Case Study of Urban New Developing Zone of Hefei City, Anhui Province

1 Introduction

One of important goals in planning for urban new developing zone (UNDZ) is maintaining sustaining ecological functions and processes.

During rapid urbanization, urban sprawl has drove a mass of new constructions which leads to more serious urban sprawl, and causes destruction of ecological integrality and decay of land ecosystem services. Ecosystem service functions of many rivers, lakes and wetlands, such as discharging and storing floodwater, are gradually lost, presenting as frequency of flood and drought. The constructions of development zone, highway, hydraulic engineering (such as dike, sluice and reservoir), tidal flat reclamation and so on disturb the balance of inhabit, presenting as decline of bio-diversity.

With the thought of development, most current plannings estimate the size of urban built-up area in future according to the population prediction. Based on the concept of environmental capacity, some plannings discuss the growth limit of urban built-up area. However, they neglect the restriction of ecological protection on urban space development. How to prepare a win-win strategy for UNDZ has become a key issue for sustainable urban development.

UNDZ of Hefei City, the capital city of Anhui Province, is located in the southeast of the city and between Chaohu Lake, 15 km far from the city centre, and planned as the city's new municipal, business and residential zone with a size of 190 km^2. Heightening and solidifying river embankment and river canalization, including artificial bending cutoff, river bed contraction, and river bank solidification, are used for flood control in Hefei city construction, so that it makes the rivers and lakes in Hefei be an engineering system under manual management. In addition, a mass of urban constructions have disturbed and are disturbing the balance of ecological inhabits. Therefore, ecological protection, especially the protection of hydrological and ecological processes, is very important in the planning of UNDZ of Hefei City.

2 Theories and approaches

2.1 Theories

Ecological infrastructure (EI) is defined as the structural landscape network that is composed of the essential landscape elements and both existing and potential spatial patterns that are of strategic significance in safeguarding the critical natural, biological and cultural processes, which are critical in securing the integrity and identity of the natural and cultural landscapes, and in securing natural capital that support sustainable ecosystem services (Yu et al., 2001, 2005, 2005).

Landscape security patterns (SPs) are identified for the individual targeted processes. SPs are composed of elements and spatial positions that are strategically important in safeguarding the different processes of the landscape. Models including suitability analysis, minimum cost distance and surface analysis were used in the identification of security patterns for the individual processes (Yu, 1995, 1996). Alternative security levels - low, medium and high - are used to define the quality of the SPs in safeguarding each of the targeted processes.

2.2 Approaches

2.2.1 Hydrological processes and security patterns for flood control

Wetland, marshland and wet woodland in Floodplains have the significant adjustive effect on the flood disaster; on the other hand, it's the proportion of river system which offers diversified ecosystem. River conservation area should be extended, including the adjacent areas which have the connection in water system (Gardiner et al.,1997). Therefore, the purpose of flood security patterns is to build spatial patterns in accordance with natural water cycle.

A complete flood control system is composed of anabranch, wetland, reservoir and bottomland. Based on the drainage basin, the flood security patterns conserve the wetland and buffer area of the river channel to protect the water cycle, and control certain key areas in space to reduce the damage of the flood disaster. The capacity of the wetland and the buffer distance of the river channel are the two important parameters, and the flood security patterns are to connect these two dynamic systems. With the help of GIS, using the runoff model and digital elevation model (DEM) to simulate the processes of the flood, the results are the decision-making background of the security patterns.

2.2.2 Urban biological processes and security patterns for biodiversity conservation

(1) Selection of indicator species

Analyzing artificial interference and impact on potential habitat pattern is to probe into possible approaches of biological protection in the background of serious fragmentation of habitats, by searching into biological processes of existing, foraging and migrating, and biological behavior pattern of horizontal spread and habitat selection. It is necessary to protect primary habitats of wildlife, as well as to analyze their home range and active paths. Existence of rare animals will be directly affected if massive construction destroys paths and space for their foraging and mating.

Usually, species in a region is of great richness, and it is impossible and unnecessary to study every one of them in urban planning. It is feasible to select some species to indicate habitat situation in certain regions. In a region with intact habitat and rich species, selected indicator species should be sensitive to habitats, and the standards include (Yu et al., 1998):

A. rarity and peculiarity of the species, and the threatening and practicality of it;
B. status of the species in ecosystem and the community;
C. evolution significance of the species.
And other standards:
A. implementation of current or planned habitat protection program;
B. species in need of big or peculiar habitats.

(2) Suitability analysis for habitats

Suitability analysis is in common use in ecological planning. Taking landscape type as unit for evaluation, the suitability and restriction of landscape type as habitats is decided and its suitability is graded according to requirements of living environment of studied species, such as altitude, gradient, type of land use and land cover, distance from urban built-up area, etc.

(3) Security patterns for urban biological processes

Animals in UNDZ of Hefei city is mainly Ardeidae, most of which lives in wetlands and woods. Ardeidae is very sensitive to artificial disturbance and its habitat range continuously shrinks because of artificial disturbance, like wetland demolishment, deforestation, roads building and urban construction. Therefore, not only the analysis of the suitability of its habitat, but also the analysis of its horizontal activity in space is necessary to establish security patterns for biodiversity conservation.

The types of vegetation in habitat, where Ardeidae prefers to live, are similar and could be used to simulate the processes of species traversing different landscape units by “minimal cumulative resistance” (MCR) model (Knaanpen et al.,1992;Yu,1995). First of all, identify sources, where suits certain species living; then a accessibility surface should be set up by simulating the processes of these dispersal target species overcoming resistance in landscape according to their spatial moving principles, and based on the characteristics of the accessibility surface, the security pattern elements except the source habitats could be recognized; buffer zones, inter-source linkages, radiating routes, and strategic points could be identified by spatial analysis of minimal resistance in species’ movement, thus composing security patterns for biodiversity conservation. (More details in Yu,1995,1996)

SPs have different patterns and ranges at different protection levels or security levels. A lower security level means a smaller protecting area and less spatial linkage, which may maintain nothing but the survival of certain species, and conversely, security patterns at a higher level cover larger geographical scope, relating to larger protecting area and more sound spatial linkage.

2.2.3 Ecological infrastructure

Taking all these hydrological processes and biological processes of the security patterns, an integrated regional ecological infrastructure will be established. They all together guarantee the health and security of regional ecosystem services. For the security patterns of various processes differ because of security standards, the overall EI formatted by their integration will also have a variety of spatial structure corresponding to different security standards, which is a group of multiple solutions between the highest (when the security standards of all SPs are the highest) and the lowest standards (when the security standards of all SPs are the lowest).

On the basis of EI, the growth processes of urban built-up area under the influence of the flood, biology and other factors could be further simulated. The results reflect the development trend of the city in the framework provided by EI, such as the size and scope of urban development area and its relationship with natural elements. The current urban built-up area can be the sources of the simulation, in which the accessibility surface is established, based on the floods, biological security patterns, the current land use, roads and so on.

3 Results

3.1 Analyses of water

Because the UNDZ of Hefei city is threatened by flood coming from Chaohu Lake, the study mainly focuses on the effect of Chaohu Lake in analysis of water.

The Chaohu Lake and the riverside water logging area, ancient river channels, bottomland, pond and paddy field are the key factors to manage the flood. Based on the elevation data and map, the potential accumulative areas can be recognized: (1) the areas tend to water logging, such as polder area along the Nanfei river and the Shiwuli river, including Dongda polder, Dazhang polder, Shangzhang polder, Xiaozhang polder, Yangpo polder, Hanlin polder, Wangjia polder and Hejia polder, and polder area along the Paihe river, including Beilao polder, Yangdu polder, Huangjin polder, Niujiao polder and Dazhong polder. These polders' elevations are below 9m, and they are planned as the flood storage place when the flood comes. (2) Using the unconstraint surface runoff analysis, calculating the storage of water in the bottomland, they are the potential areas to store the flood.

According to the different flood risk frequencies of Chaohu Lake, we combined digital elevation model with GIS-based analysis to stimulate flooding range and to establish diverse wetland scales and patterns under the condition of five different flood control security patterns defined by five frequencies (one in 10 years, one in 20 years, one in 50 years, one in 100 years, and one in 200 years). And we also calculated the flooded areas and detention volumes within given flood risk frequencies (Tab.1).

Tab.1 Different water levels, flooded areas and detention volumes within given flood risk frequencies (without embankments)

risk frequency	Water level (m)	flooded area (km^2)	detention volume (100 million m^3)
1 in 10 year flood	11.6*	70.20	1.79
1 in 20 year flood	12.5*	82.00	2.48
1 in 50 year flood	12.75*	85.28	2.69
1 in 100 year flood	13.3**	92.05	3.18
1 in 200 year flood	14.5**	103.90	4.35

The water level data sources:

*** Wang Yongchang (2000). ** The interview with Planning Bureau of Hefei City.**

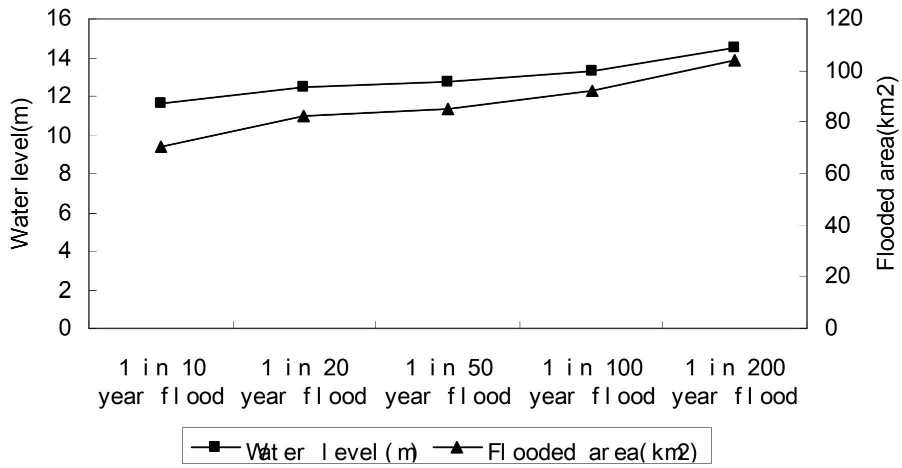


Fig. 1 Comparison between different flooded areas within given flood risk frequencies

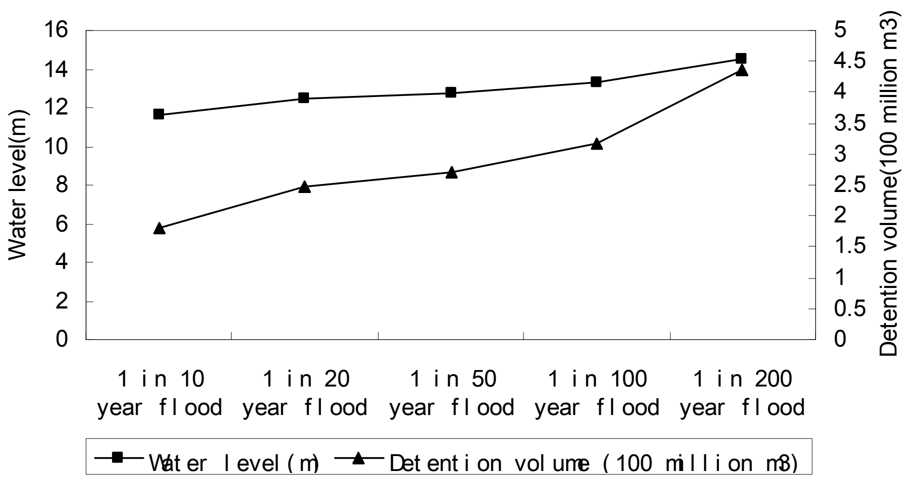


Fig. 2 Comparison between different detention volumes within given flood risk frequencies

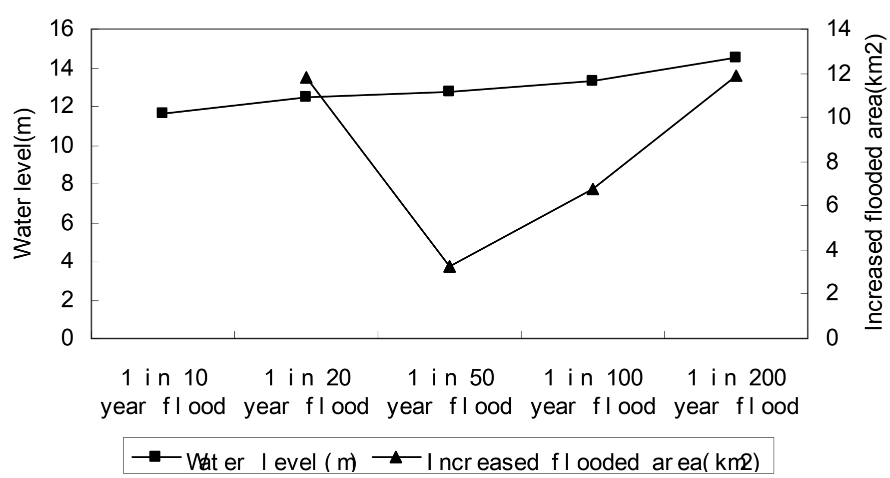


Fig.3 Changes of flooded areas within given flood risk frequencies

The above analyses (Fig.1~3) indicate that the flooded areas increase by only 2.72 km^2 when the water level rises from 12.5m (the flood risk frequency is one in 20 years) to 12.75m (the flood risk frequency is one in 50 years). Under such circumstances, there will be no need for the construction of the dam because at the cost of a small amount of construction land, a higher standard of flood control is accessible. When the water level rises from 12.75m (the flood risk frequency is one in 50 years) to 13.3m (the flood risk frequency is one in 100 years), flooded areas will increase by 6.77 km^2; When the water level rises from 13.3m (the flood risk frequency is one in 100 years) to 14.5m (the flood risk frequency is one in 200 years), flooded areas will increase by 11.85 km^2; In both cases, it will have to give up more land for construction.

Because of being the provincial capital city, the standard of flood control for Hefei city should be one in 200 years according to the national standards, the UNDZ of Hefei city should be one in 100 years flood standards. If the standard of flood control for the UNDZ of Hefei city set to be one in 50 years, it is possible to raise its actual flood control capacity up to one in 100 years through a series of planning and management measures, such as to only allow land for recreational functions between land in the one in 50 to 100 years flooded areas.

Therefore, the standard of flood control for the UNDZ of Hefei city will be one in 50 years on the lower level of flood security patterns, one in 100 years on the medium level, and one in 200 years on the higher level.

Meanwhile, the width of the river buffer will be rationally determined by the requirements such as the flood discharge, pollutant dilution and animal migration under different security standards (combined with the analysis of biological processes).

The regional flood plain wetlands and river networks with corresponding scales and patterns together with regional reservoirs, lakes and other landscape elements compose an overall security patterns for hydrological process (Fig.4).

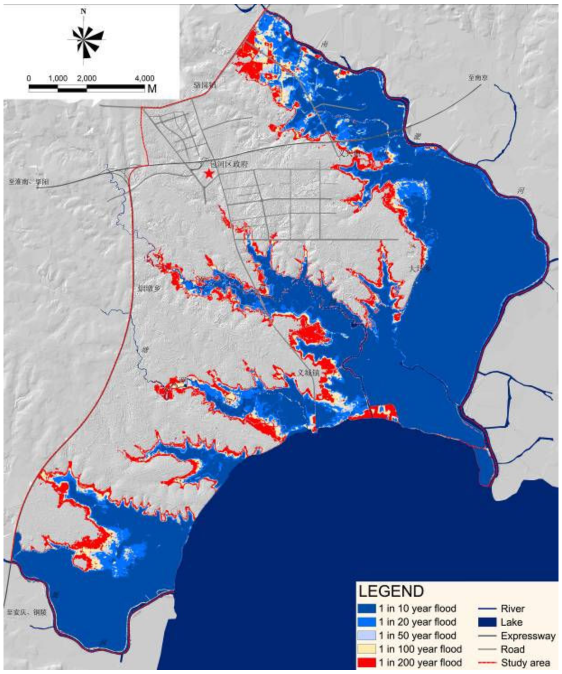


Fig.4 SPs for hydrological processes

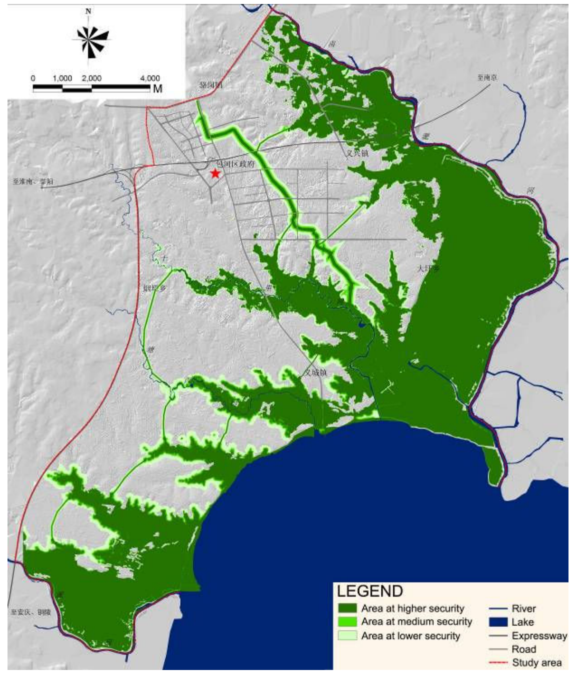


Fig. 5 SPs for biological processes

3.2 Analyses of biology

Some Ardeidae is initially selected as the indicator species of the UNDZ of Hefei city, including egret, intermediate egret, great egrets, herons, purpleheron, Night Heron, chinese pond heron, cattle egret, green backed herons. The feeding radius of most Ardeidae is 7~15km, the habitat radius is 2km, the flush distance is about 30m, and other habits is as the following table (Tab. 2). Herons habitats are similar. Compositing the situation of field observation, egret is finally chosen as the indicator specie of the UNDZ of Hefei city.

Tab. 2 Habits and habitats of indicator species to be selected

Species	Latin genera name	Residence status	Habits
Egret	*Egretta garzetta*	Resident bird or migratory bird	Paddy field \ lake \ river \ marshland, nesting in tree or reed
Intermedi ateegret	*Mesophoyx intermedia*	Migratory bird	Paddy field \ lake \ marshland \ mangrove \ coastal mudflat, nesting with other water birds
Great egrets	*Casmerodius albus*	Migratory bird	Humid or shallow water area
Herons	*Ardea cinerea*	Migratory bird	Unsociability, predation in shallow water area. Sometimes in group in Winter. Habitat in the tree.
Purpleher on	*Ardea purpurea*	Resident bird	Paddy field \reed\ lake \ river, nesting in big group

Night Heron	*Nycticorax nycticorax*	Migratory bird	Habitat in the tree in daytime, eating dispersion in the evening in the paddy field\ grass and sides of water channel
Chinese pond heron	*Ardeola bacchus*	Migratory bird	Paddy field or shallow water，eating alone or in small groups. nesting with other water birds
Cattle egret	*Bubulcus ibis*	Migratory bird	Predat flies coming from grassland drawing by livestock or buffalo. Nesting in groups on the water.
Green backed herons	*Butorides striatus*	Migratory bird	Pond\river\paddy field\reed\shrub\mangrove, where have thick cover. Nesting in small group.

Sources：

Ding Lizhong, Xu Gaofu, Lu Jianbo, Zhang Desan, Fang Bingfu (2005).
Wang Song, Yi Shangjun, Bao Fangyin (2001).
Wang Yanping, Chen Shuihua, Ding Ping (2004).

Egret in the UNDZ of Hefei city seasonally habitats in paddy fields and wetlands surrounding the Chaohu Lake, Shiwuli River, Tangxi River and Pai River, and nests in trees or reed leaves, which always keep distance away from the urban built-up area. Egret's habitat types and distribution are found out by suitability analysis in the UNDZ of Hefei city, so to meet their need of choose habitat.

In the processes of establishing biological security patterns, it is not realistic to protect all paddy field, one of the Egret favorite habitats, since there will be a great deal development needs in future. However, most of the southeastern land is paddy fields, wetlands and low-lying under the greater threat of floods, so it takes the land under the water level of one in 100 year flood as sources, the Egret future habitat conservation areas. Then, the accessibility surface is established according to the types of land cover and habitat suitability analysis. Finally, security patterns for biological processes are established on different security level (Fig.5).

3.3 Establishment of EI

3.3.1 Establishment of EI

Based on security standards of higher, medium and lower level, EI providing integrated ecosystem services is established to maintain the processes of hydrology and biology, by integrating security patterns for hydrological and biological processes, and an image of *the city of aigrette* for UNDZ of Hefei City is developed. Furthermore, the quantity of aigrette inhabiting here would be one of important indicators for monitoring the extent of urban ecological security. Hopefully people are going to live with aigrette in UNDZ in future while the EI is established.

The EI based on the medium level is recommended according to the demands of protection and development. It also shows the EI based on the higher level and lower level to refer (Fig.6).

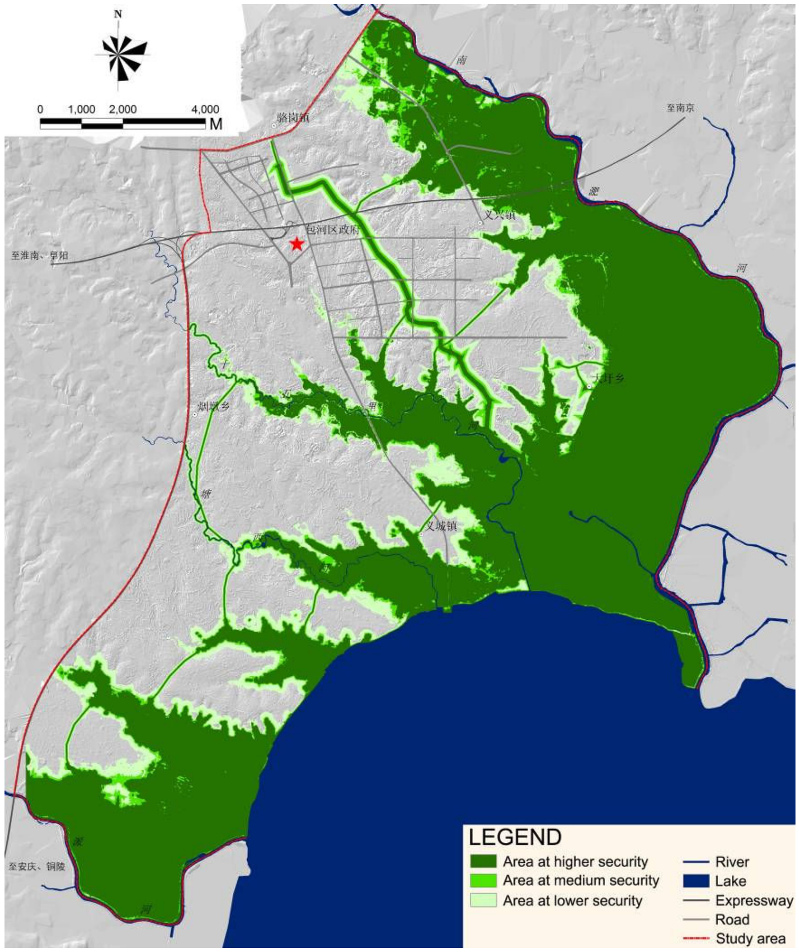


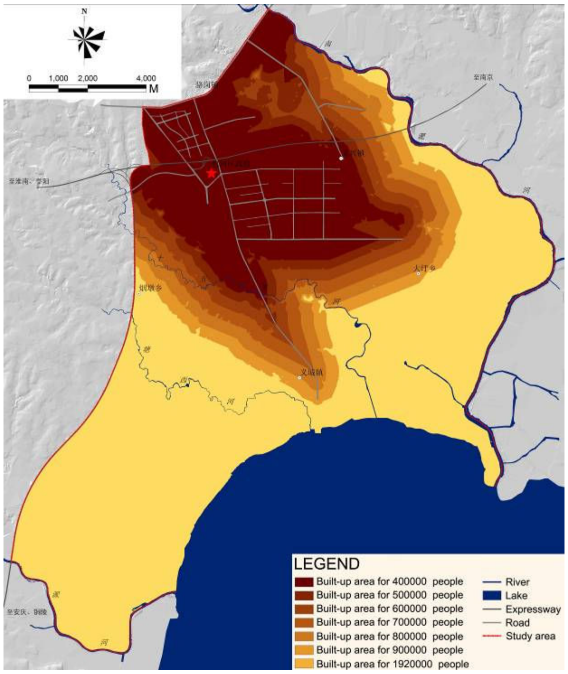
Fig.6 EI

3.3.2 Scenarios of urban growth patterns based on EI

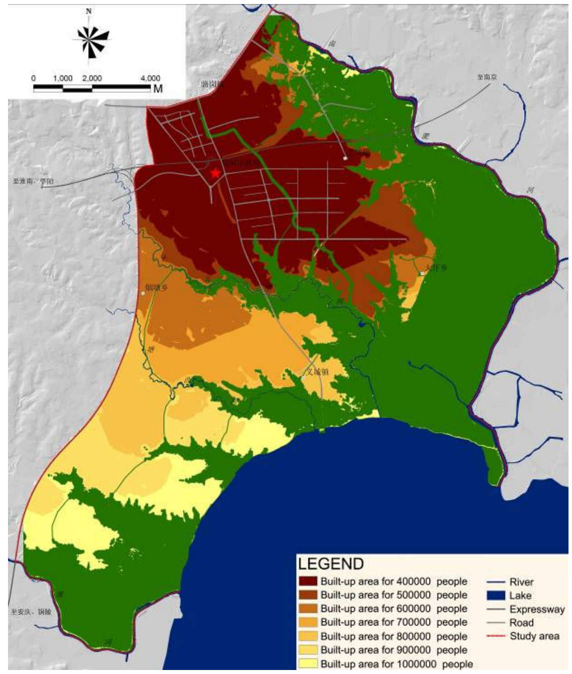
The size and patterns of urban built-up area vary with EI based on different security level. However, there is a maximum limit for urban built-up area on different security level in theory. According to national standards, constructive land per person in Hefei city is suggested to be 100m^2, so it is possible to calculate the city scale (Tab. 3) and develop scenarios of urban growth patterns (Fig.7).

Tab. 3 City scale under different security level EI

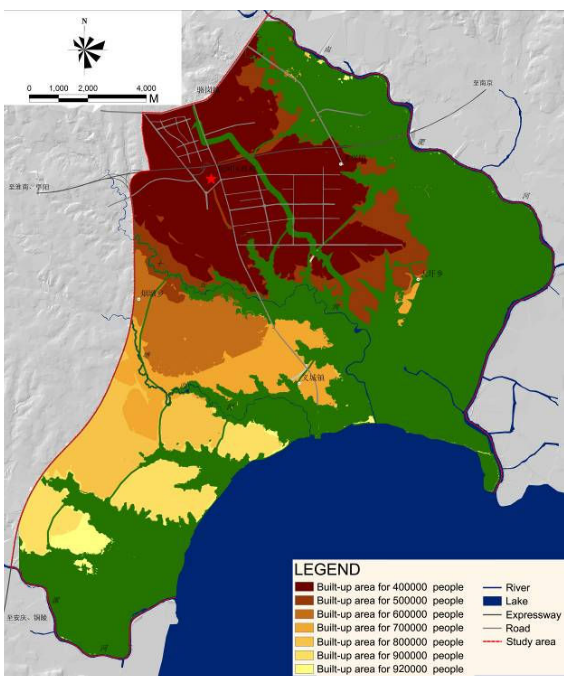
security level EI	Urban built-up area (km^2)	Population (10^4 people)	Max percent of urban built-up area in planning area (%)
Lower level	100	100	52.63
Medium level	92	92	48.42
Higher level	74	74	38.95



(a)



(b)



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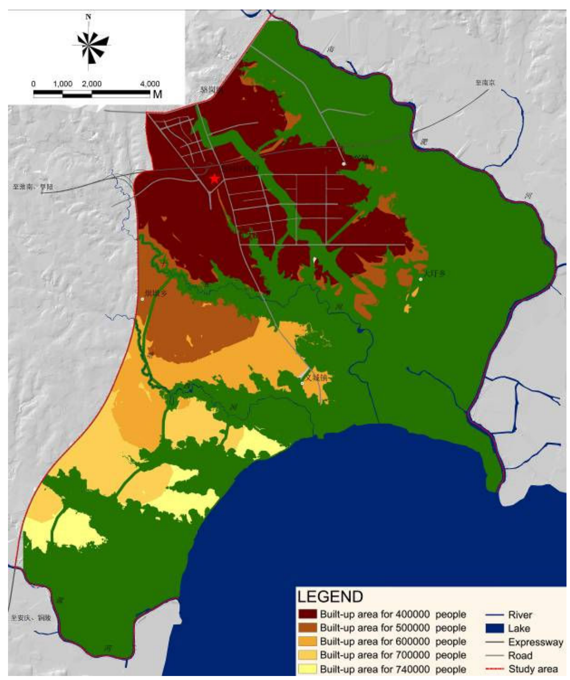

(d)

Fig.7 Scenarios of urban growth patterns based on EI ((a) without EI ;(b) based on lower level EI ;(c) based on middle level EI ;(d) based on higher level EI)

4 Discussion

Since the general framework of urban spatial development has been determined basically, the relationship between ecological infrastructure and urban construction land of different types should be taken into consideration comprehensively in UNDZ of Hefei City land use planning, to maximize ecological efficiency. I.e., residential land compatible with EI highly, could be laid neighboring EI in order to not only benefit protecting ecological infrastructure and the function of ecosystem services, but also improve the environment of residential area and add value to the residential land to some extent.

To assure the function of ecological infrastructure, general coordinating principles are suggested for ecological infrastructure establishing and urban construction:

(1) urban function and traffic system should be planed reasonably in UNDZ;
(2) Ecological corridors and patches, having critical value to the integrity of urban and regional ecosystem function, should be protected strictly;
(3) Each cluster in urban built-up area should be linked to each other and regional ecological infrastructure as a whole by the existing water surface, river system, and terrain.
(4) Any construction should be ecological and energy-saving.

5 Conclusion

The urban planning strategy developed herein is to prioritize the arrangement of ecological infrastructure, based on landscape security patterns, by means of topography, hydrological and ecological processes modeling, and to incorporate factors such as urban flood control, stormwater management, and indicator animal of aigrette which is the most representative bird in this area.

The main conclusions are as follows:

(1) An image, *the city of aigrette*, is developed for UNDZ of Hefei City. Furthermore, the quantity of aigrette inhabiting here would be one of important indicators for monitoring the extent of urban ecological security. Hopefully people are going to live with aigrette in UNDZ in future while the ecological infrastructure is established.
(2) The land used for city construction at most is between 38.95% and 52.63% so as to sustain the integrality of the ecological process and the sustainability of ecosystem services.
(3) Based on the ecological infrastructure in UNDZ urban land use is arranged according to the compatibility of different land use types to maximize ecological benefits.

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