Analysis of Framework and Optimization of the Urban Natural Landscape System (UNLS)

Case Research of Eco-efficiency of UNLS in Tianjin, China

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1 Introduction

With the accelerated process of urbanization in China, the rapid urban construction has caused serious damage to the ecological environment of the cities. Although more attention has been paid in recent years to the reconstruction and management of the urban environment during and after the construction process, there are still problems to be solved when planning to construct urban green space systems to enhance the function of the urban ecological environment [1, 2]. This is the key study of urban landscape planning, designing, ecology and other disciplines.

Much scientific research has confirmed that an urban green system improves the function of the urban ecological environment. Many analyses and researches have been done on green land factors [3]. This research includes analyses of the urban green land system [4], valued ecological function and construction indicators of urban green systems.[5], These analyses have revealed some indicators of urban green systems [3, 6, 7], such as: per capita public green area, urban green land rate, green coverage, green quantity and green seeing rate. These analyses have promoted the improvement of the ecological functions of urban green space.

However, with the development of Urban Science and Ecology, urban–rural integration theory and the concept of three-dimensional urban greening, ideas and theories of landscape pattern have gradually seeped into every aspect of urban construction [8]. Urban green space has gradually been absorbed into the peri-urban natural environment [9].

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The traditional urban green land system has limited the urban built-up area, which increasingly cannot adapt to the needs of urban ecological construction. Green space in urban areas is no longer just green land [8]. Some urban land is covered with pavement, water and other constructed elements, and three-dimensional afforestation and roof afforestation have been gradually built up [10].

So, the green land system should evolve into an urban natural landscape system, including the urban open and built-up surroundings. In this open space one can use the hardscape and soft nature landscape.

The urban natural landscape system is the meso-scale system, including the urban green land system of built-up areas (this is the urban green land green aforementioned) and certain suburban environments. It would introduce the suburban natural landscape's ecological effects into urban center through the construction of urban–rural integration [11]. The function of ecological protection and improvement of the UNLS can be explained by optimization methods. And the built-up area of the suburban environment can be integrated with the protective film for the urban environment and give the urban green space a healthier and organic quality [12]. The quality of the urban eco-environment will be improved and a pleasant living environment for urban residents will be created.

2 Structure and Framework of UNLS

2.1 Structure Elements of UNLS

The suburban and built-up areas of urban regions are two parts of the UNLS. There are different ways to understand these elements.

Most of the urban landscapes are artificial scapes, in which little persists from nature. So there are two types of urban landscape according to their properties: artificial landscape and retained pure natural landscape. The artificial landscape in urban areas is informed by and sourced from its origin in nature. The artificial landscape is more concerned about a beautiful visual effect, although the ecological role is also important. In retained pure natural landscape, on the one hand, ecological value is more important; on the other hand, it is also valued for its associated history.

If the classification is according to foundation and appearance of the landscape, there are two types of the urban landscape: landscape and waterscape [13]. Landscape includes both the land covered with vegetation and that covered with hardened paving. Waterscape is the area in which water is the main landscape factor. Waterscape includes wetlands, lake landscape, river landscape etc. Landscapes and waterscape are the majority of roles in the urban landscape in the eco-environment. Their aesthetic value is also an important part. In a modern landscape, more and more landscapes are paved with hardened materials. Hard-paved landscapes weaken the ecological function of the landscape, but they also have special features

and carry out the function of corridors. So, according to those special features, hard-paved landscapes should be listed as a kind of landscape.

According to the shape of the urban landscape and the role in the improvement of urban ecological function, there are four types of urban landscapes: massive green space, scattered green space, green corridor across the urban area, and suburban green space around the urban area.

1. *Massive green space*

There have been large areas of green land in urban areas, such as: urban park, district park, waterfront park and semi- preserved natural park. These parks range from several to tens of hectares in area. They typically feature rich vegetation and varied types of space for people to stay, play and do many activities. So these massive green spaces have higher eco-efficiency and are the most important space in urban areas.

2. *Scattered green space*

Scattered green space is the small green space distributed in urban areas. Such areas are dozens to hundreds of square meters; the larger green spaces are thousands of square meters to several hectares.

They spread to the sides of street, in yards belonging to building units or enterprises and in residential districts, etc. The scattered green space is the foundation of the urban green space and is the ecological matrix of the urban landscape.

3. *Green corridor*

In urban area, the road, street, and river are the continuing factors crossing the entire urban area or district. They are often decorated by vegetation and some hardened paving. That builds on the green corridor to contact the massive green space with the scattered green space, integrating them to form the whole urban landscape [9]. Because of the characteristic of line, the green corridor has the function of exchange of information, energy and material [14]. This is the most important function for the urban ecological environment.

4. *Suburban green space around urban areas*

On the outskirts of urban area, there always is the natural environment and it forms a green belt surrounding the urban core. These natural environments construct the protection layer of the urban environment. They protect the urban area from the bad effects of high wind, air pollution and sand-storms, etc. They also provide fresh air, water, and suitable conditions for urban greenspace to enhance the quality of the urban ecological environment.

2.2 Function of the UNLS

The four elements of the UNLS interact and achieve a virtuous cycle in the urban ecological environment, the function of which is the self-healing of the urban ecology. The **massive green space** generally has the biggest area in urban area;, its ecological function is great, and it can greatly improve the temperature, humidity and pollution in the air, such as PM2.5, and other conditions of urban areas. **Scattered green space** has smaller areas and lower levels of function, but it has the great quantity of overall area.

With the function of superimposed scattered green space combined with the massive green space function, the ecological function of the green space is greatly enhanced. Suburban green space surrounds urban and provides a virtuous outdoor environment for urban residents. It and transports good material into the urban area, such as fresh and cool air, and transports bad material out of the urban area, such as pollution and hot air. In the transport process, the **green corridor** plays the key role. It is the only channel to connect the green circle with the urban area and urban landscape. Its most important function is the exchange of ecological elements between the inner and outer urban environment [13]. Therefore, the function of the UNLS is complex. It is the superposition of function of the various elements.

2.3 Optimized Framework of UNLS

According to the analysis above, the framework of the UNLS should take the four elements into account and integrate together. Therefore, the framework should be: massive green space combines with scattered green space which promote each other; all elements connect between internal and external sides of the urban area, and the ecological cycle should be achieved.

To optimize the framework of the UNLS, it should be considered in the urban planning [13], such as:

1. The quantity, area and position of the massive green space and scattered green space are the most important factors. They are the foundation of the urban ecology. The land should be reserved to develop the massive green space and scattered green space in urban planning and renovation。
2. The suburban green belt and peri-urban natural environment are the protective layers of the urban environment. Suburban green belt should have a certain width and structure. In order to construct the layer of the urban environment, some key sections should have different structures (Fig. 1).
3. Several green channels should be reserved and planned in the urban landscape planning process. They should be located according to the position of massive green space and suburban natural environment, and their design should be coordinated with that of the urban master plan, including watersheds, wind direction, etc.

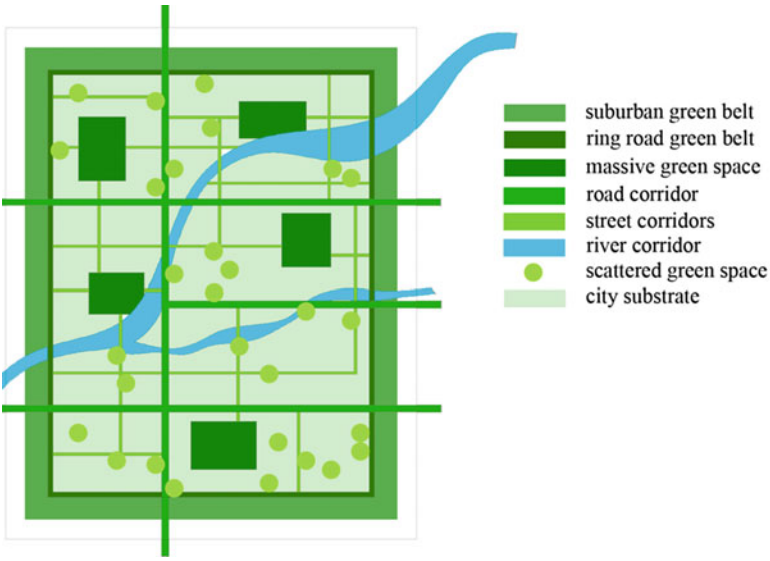

Fig. 1 Structure model of UNLS

3 Research of Tianjin UNLS

3.1 Analysis of Structure Elements

At the beginning of 2011, there were approximately 4,109 ha of massive green space in Tianjin. There are 28 parks in central urban areas. Only the Water Park area contains more than 1,000 acres. The area of the parks, such as the Zoo, Beining Park, Activity Center of Younger, Xigu Park, Chonghong Park and Nancuiping Park, are more than 300 acres. The others are not more than 100 acres.

There are 912.5 ha of protectedgreen space in Tianjin's urban green space system. The protected green space inside the urban area it accounts for 5.7 % of the urban green space; scattered green space is 6449.3 ha. There are 345 main roads in the city, and green rate of the roads is 21.5 %.

3.2 Overall Layout of Urban Green Space

The massive green spaces are mainly located in the south and north of the urban area. The south's massive green spaces are aesthetically more pleasant than the north's and there are many lands that have never been greener.

The center of the urban area is the old urban district; there is only some little urban space. There is no massive green space; the area of the green space is not more than 2,000 m^2 (Fig. 2).

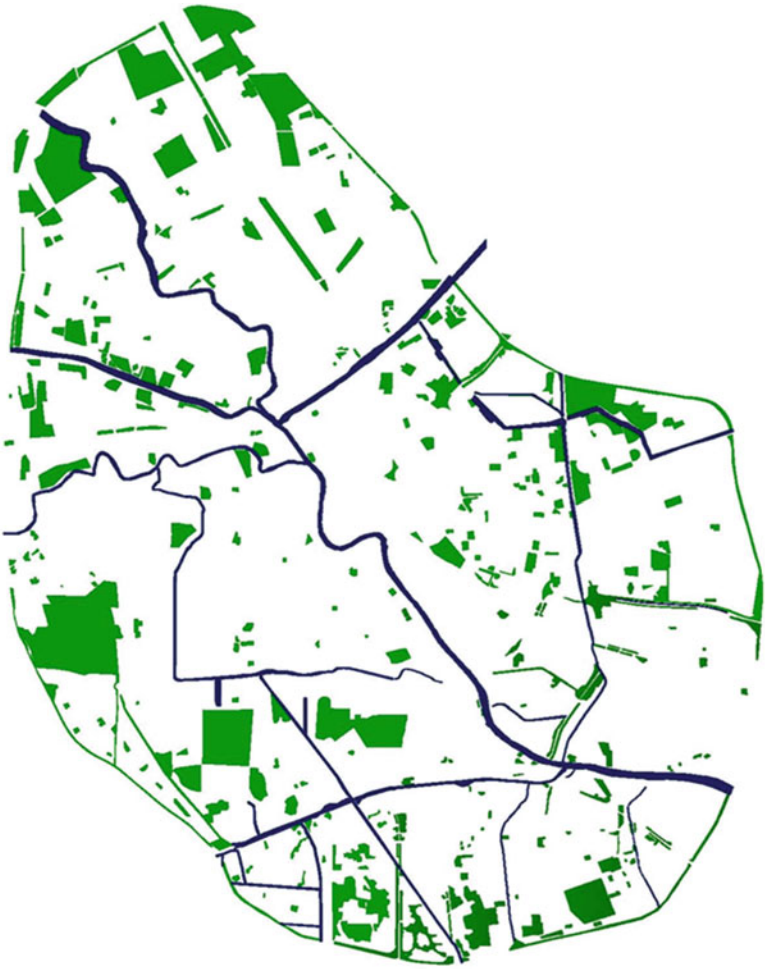

Fig. 2 Layout situation of Tianjin green space

River and street are the main line elements of the urban core. So, river landscape, belt and road green spaces are the main green corridor in the urban core. The rivers of Tianjin are the Haihe water system. There are five rivers in the Haihe water system: South Channel, North Channel, Ziya River, Daqing River, and Yongding River. In the second layer of the water system, there are 19 rivers and 6 artificial rivers including New Ziya River, Machangjian river, Duliujian River, New Yongding River, Chaobai River and New Huanxiang River. There are many streets in Tianjin including surrounding roads, a quick road, middle quick road and other streets distributed in city districts. Some green spaces on streets are street green land.

3.3 Assessment of Eco-efficiency of Tianjin UNLS

In order to analyze the eco-effection of the UNLS, the research used temperature as the indicator to discuss the relationship between the green space area and the temperature effect..

When the urban green space area is 1–2 ha, it has a certain humidification effect, but the cooling effect is not obvious. When the green space area is 3 ha, the river effects of cooling and humidification are obvious; when the green space area is 5 ha, the cooling and humidification effects are very obvious; when the green area is greater than 5 ha, the cooling and humidification effects are extremely obvious and uniform. Some research indicates that when the green space area is more than 3 ha, it is capable of stable internal space humidity conditions, and makes a greater contribution to the surrounding environment [15].

3.4 Analysis and Assessment of Green Space Temperature Buffer

1. *Buffer analysis of temperature effects in Tianjin UNLS*

According to the cooling effect of green space (Table 1) [15], the research analyzed the green space buffer, based on the size of Tianjin's urban green area, to determine the zone of the buffer (Table 2).

2. *Greenland buffer evaluation*

From the buffer analysis diagram of the Tianjin UNLS, it can be seen that the third buffer range accounts for about 30 % of the urban area. It is mainly in the urban area's southwest side, north, east side of the city. And in the center of the urban area, the green space buffer area is rare. It is mainly due to large area of green space in the heart of the urban area, which is smaller, scattered, and does not make up a system. Therefore, the ecological effects of green space are smaller, the heat island effect is stronger, and compared to the edge of the city in the summer central urban temperature is higher than that in the edge district.

The River green belt in Tianjin includes the Haihe and Ziya Rivers, bringing the cool air from the suburbs. Especially, on both sides of the river in recent years in Tianjin, the rebuilding engineers have extended the big area of green space. It developed by widening and adjusting the structure of the river belt green space. It enhanced the corridor function of the belt with combining the ecological benefits of river green space and water. But for the reason of the narrow green space in the road and street belt, there is little effect on the urban eco-environment. So, efforts should be focused on the building of the road and street green belt in Tianjin UNLS.

From the analysis of the buffer, the overall layout appears that there are fewer green spaces in urban center, but it is great in edge district. And in the center of the

Table 1 cooling effect and radiation range of green space (about 14:00 in summer) [15]

Green space	Green space area (ha)	Temperature reduced (m)	Temperature difference (°C)
Shinjuku Imperial Garden	58.2	100–350	0.3–0.2
Koishikawa Botanical Garden	16.1	100–250	0.3–2.3
Zenpukuji River green	17.7	100–200	0.5–1.0
Grove of or? park	0.05	5	0.5

Table 2 Buffer of green space according to the size

Types of green space	Size of green space		Range of buffer (m)			Remark
			First buffer	*Second buffer*	*Third buffer*	
Massive green space (ha)	1	Areas more than 50	100	200	300	Green space includes water-scape, green land, paving land, etc.
	2	Areas more than 20 less than 50	50	100	200	
	3	Areas more than 5 less than 20	20	50	100	
	4	Areas more than 3 less than 5	20	40	60	
	5	Areas more than 0.5 less than 3	5	10	20	
Corridor green space (m)	1	Width more than 50 m	100	250	350	River width is included
	2	Width more than 35 less than 50	60	130	200	
	3	Width more than 15 less than 35	20	50	100	
	4	Width more than 5 less than 15	5	15	30	

urban area, the green spaces have not connected with each other. That upset the balance of the green space system. Though, the indicator of the green space of urban can achieve the standard to a certain extent. But the effect on the urban environment could not reach the requirements of comfort and livability for the whole city (Fig. 3).

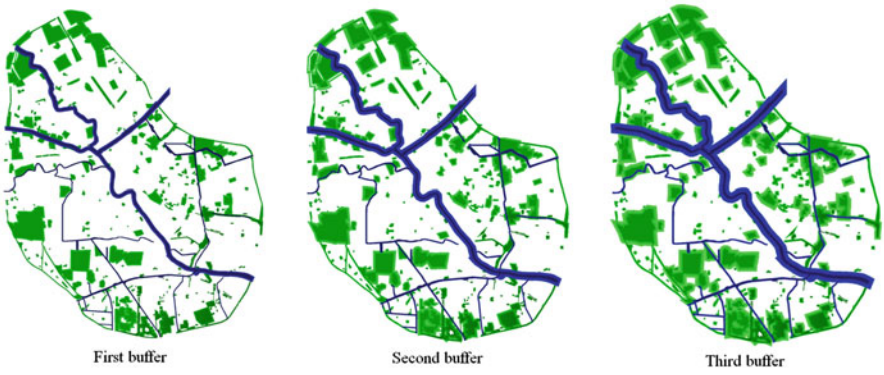

Fig. 3 Buffer analysis of temperature of Tianjin urban green space

3. *Optimization of Tianjin UNLS*

(a) *Overall framework*

Massive green space is one of the main green space types of urban ecological environment improvement. According to the characteristics of the Tianjin urban green space, the three layers system of urban parks should be improved in the central city of Tianjin to form an urban center with massive green space; urban parks, district parks and community parks. Urban parks are the urban ecological security. They should meet the needs of all residents of urban areas, from sightseeing to leisure, communication and other activities. District parks are the assistants of urban security; the vegetation-scape should be emphasized and the plant communities should be paid more attention. Community parks are the ecological protection auxiliary area. They serve the community for morning exercise, dancing, singing, playing chess and other leisure activities. Both the hardened paving and plant landscapes should be emphasized. The three level layouts of green space are the green elements of the urban area, and they are the key to the urban eco-environment.

Scattered green space is the common green space in the urban green space. It is the result of "see seam, insert green" in urban construction. Single scattered green spaces have small areas. But unity is strength. Therefore, its overall ecological effect is very important [16]. The layout of the scattered green space should be made according to the layout of massive green space and corridor green space to determine the form and plant configuration. Scattered green space is the supplement to massive green space.

Corridor green space should take the main road and main river of the urban area asprimary arteries, and take the other l type green space asauxiliary. The green space width of the subject should more than 30 m to form the communication corridors of between urban and suburban ecological environment.

Focusing on the problems of high fragmentation, layout imbalance and weak service functions, it should be solved through the green corridor construction to improve the green space connection and to dissolve isolated green space and to penetrate the scattered green space into residential areas, and municipal unit

areas [17]. With the corridor green space connection, the scattered green space could be formed as a system layout: a large green space for the nuclear, small green space for the assistance, street green space and small garden for green point and small green corridor for connection.

(b) *Suburban green space around urban areas*

Suburban landscape forest belt and country parks are the main types of suburban green space around urban areas. It should be a corridor protecting the urban environment to mitigate the hazards of dust storms, industrial pollution and soil erosion. It should be built with the urban winds in mind, and to form a barrier to harmful climate and a corridor to favorable climate. The country parks should be built according to urban massive green space and corridor green space, to strengthen the liquidity of the inside and outside of the urban green space system. It should also dissipate bad quality air from the urban areas, and purify and import the good quality air to urban areas, to improve the urban ecological environment.

4 Conclusions

The urban natural landscape system is the basis of the urban ecological environment. Its structure should include massive green space, scattered green space, corridor green space and suburban green belt encircling urban areas (including country parks). Massive green space in urban areas should account for a large area to be set aside in urban planning, and to ensure proper size and location, so that it can meet its ecological effects and improve urban eco-environment.

Scattered green space is the basic green space in urban areas. It supplements and strengthens the ecological functions of the massive green space. It should be rationally distributed in urban areas, and distributed across the city, so that every corner of the urban area will be full of green, and the urban ecological environment will be improved.

Corridor green space is the only way of communication between urban and suburban ecological environments, and the way of exchange between the different green spaces [9]. More attention must be paid to the building and strengthening of corridor green space. It should be planned as a reasonable construction with width, structure and vegetation to organically link the internal artificial environment and the external natural environment, to communicate and exchange environmental resources and improve the ecological environment to get self-circulation and eco-balance.

The suburban green space around the urban area is the protection of the urban environment, and also is the transition of the urban artificial natural environment to the outside natural environment [18]. To strengthen the planning and construction of the structure and function of the suburban green belt could provide an excellent natural resource base for the artificial natural environment of urban areas and integrate it into natural environment to improve the quality of urban eco-environment.

Of all the elements of UNLS, the planning and construction of corridor green space is the weakness in modern urban landscape planning in China. In recent years, the planning and construction of urban landscapes in the river landscape and avenue landscape areas has made significant development. But most are based on urban beautification, on the reason of urban scape and image. The function of ecological improvement of the green space has not been studied previously. Therefore, plan and construct urban corridor green space in accordance with its ecological function, communication function, etc. To link the point (massive green space), surface (scattered green space) and ring (suburban green belt ring urban) spaces and enhance the ecological function of UNLS, blend the UNLS into the natural environment.

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