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Urban forest in Jinan City: Distribution, classification and ecological significance

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Abstract

Urban forest mainly refers to urban green space and suburban forest. Urban forest is quite significant in reducing negative effects of civilization and preserving the ecological balance of city ecological system. This paper applied remote sensing method in the study of urban forest in Jinan City. Results show that there are various kinds of greenbelts in Jinan City, including public greenbelt, residential greenbelt, greenbelt attached to branches, protective greenbelt in production, landscape forest and road greenbelt. The urban greenbelt area is limited, the layout is irrational, and development of the scenery forest is slow.

Using the remote sensing investigation, we divided the suburban forest into seven classes: protective forest, intercrop forest, economic forest, sparse forest, non-afforested forest, forest web and scenery forest. Current forestlands are scarce and asymmetrical, the layout is unreasonable, plant diseases and insects are serious, and the growth rate is slow. The existing forests are not effectively managed and the reforestation on desolate hills is difficult.

Based on the research, suggestions to improve urban forest in Jinan City are given as follows: increasing the number of greenbelt corridors, creating sequential plane greenbelt, developing three-dimensional green space, carefully selecting and comparing the tree species, programming reasonably and overall distribution.

Keywords: Urban forest; Remote sensing; Evaluation; Jinan City

1. Introduction

Urban forest is a complex ecological system which is closely related to urban system and embodies the harmony of natural ecology, artificial ecology, social ecology and economical ecology. The concept of urban forest was first brought forward by Erik Jorgensen in Toronto University of Canada in 1965. In his opinion, urban forest not only includes management of urban forest, but also management of forest which was influenced and utilized by city dwellers. The term "urban forestry" was first used as a title for a graduate study on the success and failures of municipal tree planting in part of Metropolitan Toronto (Johnston, 1996). Britain is the first European stronghold of urban forestry (Konijnendijk, 2003). Initially, Ireland was the only country that followed Britain in embracing the concept of urban forestry. The first major review of urban forestry in Ireland was carried out in 1994 and the first urban tree resource in Ireland (for Dublin) started in 1993 (Johnston, 1997).

There are lots of organizations that have been studying various aspects of urban forests. The Community Forests program draws heavily upon elements of the urban forestry concept, such as focus on social values and broader concept of "forest" (Davies and Vaughan, 1998). The National Urban Forestry Unit (NUFU) was set up in 1995 as an independent organization championing the need for integration of tree planting, conservation and management with different agendas, such as health, land reclamation, built development, heritage and education (NUFU, 2002).

Networking and international contacts proved crucial in the British, Dutch, Irish as well as other cases. The

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International Society of Arboriculture, set up in the United States in 1924 as the National Shade Tree Conference, gradually increased its international member base and activities to meet part of the networking demand (Johnston, 1996). Several new networks of urban forestry researchers emerged in response during the 1990s. The Nordic Forest Research Cooperation Committee (SNS) supported a first Nordic workshop on urban forestry held in Reykjavik in 1996 (Nilsson and Randrup, 1996). SNS continued to support urban forestry networking through funding joint Nordic-Baltic seminars in Tallinn (Sander and Randrup, 1998) and Kaunas (Randrup et al., 2001).

Different countries use different definition of "urban" (Forrest et al., 1999) and "forest" (Helms, 2002). As we have seen, moreover, the "forest" in urban forest is related to more than "forest" in its more traditional definition. "Other wooded land" and "Trees outside forests" are categories used by FAO for its forest resource assessments (FARs) (FAO, 2002). For example parks, gardens and street trees are to be included when they are located in (or near) urban areas. Many ecological and social processes related to urbanization affect the distribution of trees in cities (Heynen and Lindsey, 2003). These include creation and maintenance of urban infrastructure such as utilities and roads (Jim, 2003), and natural phenomena including storms and disease.

Urban forests mainly involve urban green space and suburban forest. Suburban forest is the periphery part of the urban forest. Urban green space includes arbors, shrubs, flowers and grasses in urban area, which is usually made up of public greenbelt, parks and road trees. It can provide habitats and help to maintain people's body and mental health. Suburban forest is located between a city center and far-suburban area. It uses farmland shelter as its framework, including special forest, economy forest, small quantity of wood forest and firewood forest. It has the functions of maintaining the balance of urban ecosystem, providing travel location and supply all kinds of forest byproducts.

With the development of industry and urbanization, the urban environment is worsening greatly. It is necessary to expand the area of urban forests. It is urgent to construct complete urban forest ecological system, to classify urban forests properly and administrate it efficiently. Monitoring data shows that the average temperature in the area with more than 35% green space cover is 1–2 °C lower than the one in the area with less than 10% green space cover. For years, urban forest in Jinan has reduced 150 km^2 area of soil erosion.

As is known, urban soil is one of the essential constituent parts of research that has had an important effect on the urban sustainable development. So the problems of Jinan urban soil contaminations have been paid more and more attention. During the last decade, the studies concerning the heavy metal pollution, organic pollution and biogenic pollution of surface soils in the urban areas have been conducted around the world. However, large urban areas are seriously contaminated with concentrations of pollutants. These research results could systemically provide important scientific proofs of urban ecological environment quality. Since soil contaminations in urban environment are attached with more and more concern among the international scientific communities, the recent trends and emphases in research have been put on such issues as the conception and kinds of urban soil.

In the study of urban forest, most researches focus on theoretical study. Q. Gao published "urban forest" in Taiwan in the mid 1980s. At the same time, G.F. Sheng and Y.W. Wang introduced the concept of the urban forest into China, and recommended study methods of urban forest. At present, many cities have put forward the goal of urban forest development. Currently there are 657 cities in China, and 70% of these cities initiated an inventory of urban forest resources. Some mega cities have built a database of urban forest resources with the technologies and methods of geographic information system (GIS), aerial photography and field investigation. Some basic research such as the amount of leaf area, the rate of coverage, and the component and distribution of species in cities has been carried out.

Using stock aerial photographs or other aerial imagery, photogrammetric techniques can be used to assess tree canopy cover quickly and cost-effectively. Some papers have discussed the application of photogrammetry and provided some examples of applications to distribution and classification of urban forest.

2. Description of study area

Jinan, the capital city of Shandong province, lies in the mid-west of Shandong, where the Beijing-Shanghai Railway and the Jinan-Qingdao Railway are joined together. It is the political, economic and cultural center of Shandong province. The city covers an area of 8227 km^2, with a population of 5.69 million. Jinan is located in the North Temperate Zone, and it has a continental monsoon climate with four distinctive seasons. The annual average temperature is 14 °C, and average annual rainfall is 650–700 mm.

Since China's reform and opening-up policy in 1979, Jinan has made great achievements in economic and social development. Urbanization has been developing quickly. The agricultural population has been transferring to the central city and the urban area keeps enlarging. In the process of urbanization, urban soil has been changing and the structure of the urban forest is facing changes.

With the rapid development of Jinan's urbanization and civilization, urban environment issues, such as soil contamination, soil erosion and acidification and degeneration of vegetation, are becoming more serious. These issues have been threatening the health and safety of urban forest.

According to the definition of urban forest, we mainly focus on urban green space and suburban forest of Jinan. The suburban forest ranges from speedway around the city in the east to Yufu River in the west, from speedway around

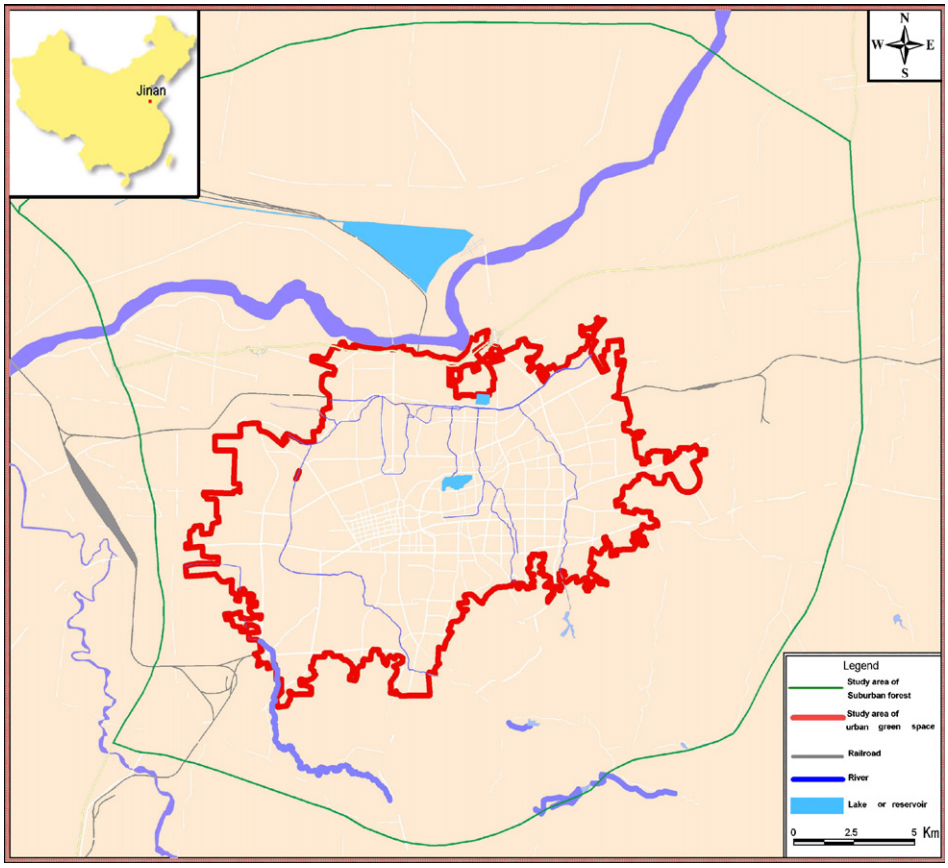

Fig. 1. The study area of urban forest in Jinan.

the city in the south (Da Jiangou) to the one in the north (No. 008 national highway) (Fig. 1). The total acreage is about 892 km^2. The area of urban green space mainly involves most parts of Jinan City zone (Fig. 1).

3. Methodology

Remote sensing can be used to obtain the basic data to study the resources of urban forest. It saves manpower and material resources, and it can provide real-time, sequential and dynamic information.

3.1. Data sources

The remote sensing used in this evaluation mainly includes combined image by LANDSAT and SPOT satellites (Jinan, 1997), Chinese–Brazil resource satellite image (Jinan, 1999), infrared aviation image of Jinan City (1:15000, 1998) and real multicolor aviation image of Jinan (1:9000, 2000). Images combined by LANDSAT and SPOT satellites, infrared aviation image of Jinan City (1:15000, 1998) and real multicolor aviation image of Jinan (1:9000, 2000) are used as major sources of information. The Chinese–Brazil resource satellite image is used as an additional source of information.

This investigation was based on two maps of Jinan City scaled by 1:50,000 (The Liberation Army General Staff Mapping Bureau) and 1:25,000 (Urban Reconnaissance Mapping Academe in Jinan City) respectively. The map was finally formed through coordinate matching with a Geographic Information System software, MapInfo 6.0.

3.2. Methods

The process of interpretation mainly involves four steps: primary interpretation, field investigation, detailed interpretation and map forming.

4. Results and discussion

4.1. Remote sensing investigation and assessment of urban green space

Urban greenbelt mainly refers to the urban land covered with natural vegetation and artificial vegetation. Urban greenbelt involves the land used as green space in the urban construction and the area with a good green space environment. According to the division standard of National Construction Board and the Department of Gardens of Jinan City, we divide the urban greenbelt into six parts: public

Table 1
Covering area of various greenbelt in Jinan City

Type of the greenbelt	Covering area ($10^4 m^2$)	Percent of the total greenbelt
Public greenbelt	850.14	16.0
Productive greenbelt	46.76	0.9
Defending greenbelt	356.97	6.7
Roadway greenbelt	208.23	3.9
Attaching unit and resident area greenbelt	1193.53	22.7
Landscape forest greenbelt	2633.95	49.8
Total	5289.58	100.0

greenbelt, resident greenbelt, greenbelt attached to branches, protective greenbelt in production, landscape woods and traffic greenbelt.

Through remote sensing investigation, we see the area covered by all kinds of greenbelt in Jinan City (Table 1, Fig. 2). The total cover of the six classes of Greenbelt is approximately 5289 ha and the total coverage is 30.1%, slightly smaller than the statistical results of the departments of gardens.

We divided the urban green space coverage rate of Jinan City into three classes: the first grade (superior), coverage rate >25%; the second grade (common), coverage rate 10–25%; the third grade (inferior), coverage rate <10%. Results show that the distribution of urban green area in Jinan City is quite uneven (Fig. 3). The first grade area of coverage mainly lies in the south edge of Jinan City and in a small part of the built-up area. The central area of the city, with a high density of population, belongs to the third grade.

From the cityscape point of view, we classified the greenbelt batches according to the area. In the urban ecological system, large greenbelt clump as a "green lung" has many ecological effects; small ones as a "stepping-stone" of immigration and resettlement of species can improve the visual effect and enhance the heterogeneity of cityscape. The statistical numbers and area of the urban Greenbelt clump in Jinan City are shown in Table 2 and Fig. 3. From this table, we can see small decorating greenbelts dominate the urban landscape. This shows the land use of Jinan City is relatively crowded.

Jinan is the largest landlocked city of Shandong province, and it has its own characteristic of cultivating trees, generally native trees are used such as *Paulownia tomentosa*, *Populus tomentosa*, *Populus canadensis*, *Sophora japonica*, *Acer truncatum*, *Salix babylonica*, *Fraxinus chinensis*, *Ailanthus altissima* and *Platycladus orientalis*. The trees for viewing and admiring are mainly *Cedrus deodara*, *Sabina chinensis*, *Sabina virginiana*, *Cercis chinensis*, *Lagerstroemia indica*, *Syringa oblata* and *Prunus cerasifera*. The urban forest is relatively monotone in green space, and the species of trees to view and admire are not abundant.

Green areas are mainly located in the suburb of the city and in a small part of the built-up area, for instance, Spring City Square, Daming Lake, Baotu Spring, Five Dragons' Pools, Park around the city, etc. cluster in the old town. The Park of the Hero Hill, the Botanic Garden and the Qianfo Mountain are distributed at the edge south of the urban district. Some places, such as Railway station, Guan Zhaying and Guan Yi Road, lie in the center of the downtown and have a dense population, thus the area of public greenbelt is small. This also shows the land use of the old town area in Jinan City is very crowded.

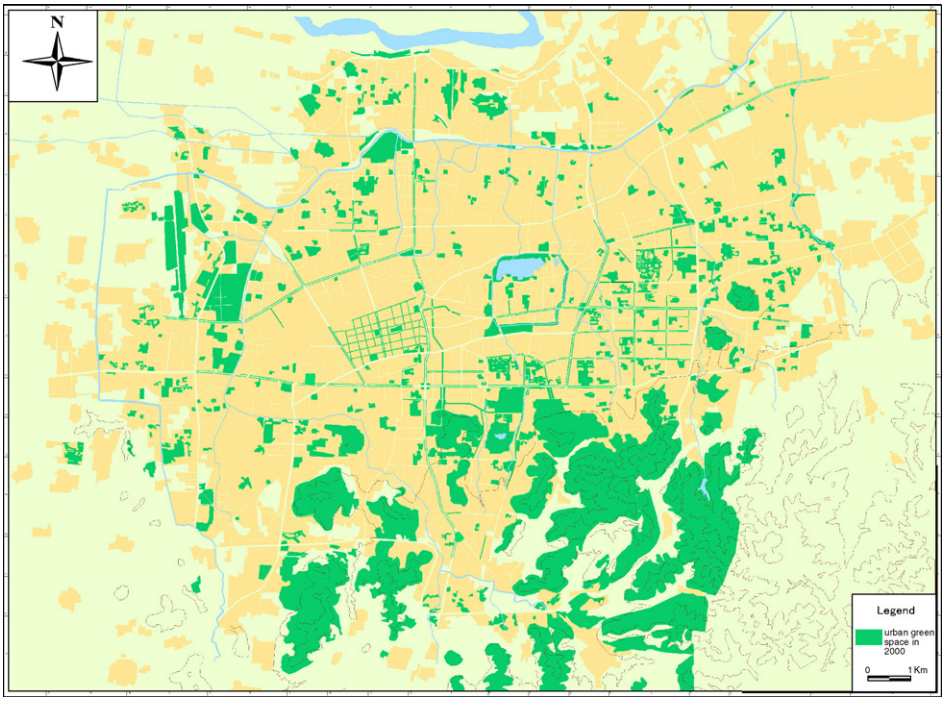

Fig. 2. Distribution of urban green space in Jinan (2000).

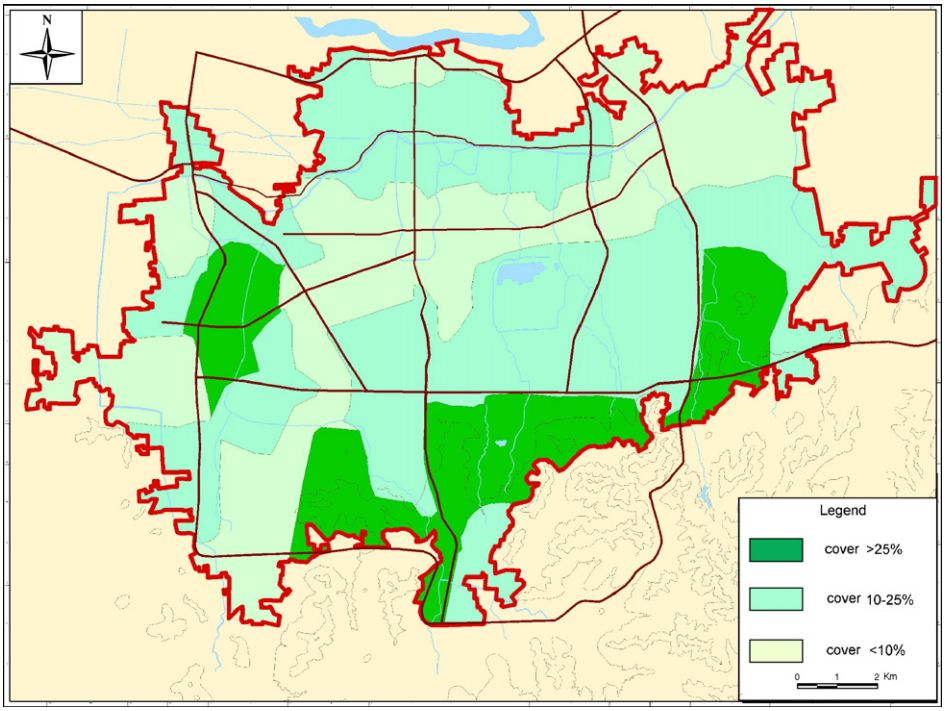

Fig. 3. The ground cover percentage of urban green space in Jinan (2000).

The urban district of Jinan City is in a low-lying basin, so the contaminative air is difficult to spread, and most industries are located in the northeast and southwest of Jinan City, which are upwind. Waste gases and smog go into the city with the wind, aggravating the air pollution of the urban district. Qingdao-Jinan and Beijing-Shanghai railway crosses Jinan City, bringing noises. The drainage canals are seriously blocked, resulting in the block of drainage on rainy days. As the trees can not be planted on the blocked river sides, the green channel to connect with the suburbs of Jinan cannot be constituted. Besides, there lacks a corresponding separate forest belt between the source of pollution and the urban area.

The scenery forestland in the south mountain area of Jinan is not only an important tourism resource, but also a source of water, where the natural resources and cultural landscapes are very abundant. Thousand-Buddha Mountain and the Dragon Hole have already been classified as the provincial scenic spots. The growth of the landscape forest develops slowly. In recent years, the phenomenon of picking stones freely is very serious, and the natural scenes have been seriously destroyed, which brings many irretrievable losses to the forest.

From Jinan's recent and historical air photos, we can see the changing history of urban forest. The general trend is: the area with low green space has little changes; the area with mid and high green space coverage has more changes. The positive point for green space changes is from public green space, while the negative point is mainly focused on areas concentrating on special use. The reasons for occupying green space are building hotels, residential area and business buildings.

Table 2
Types of urban green spaces landscape in Jinan City

Classification ($10^4 m^2$)	Type of greenbelt clump	Number of clumps	Proportion (%)	Area ($10^4 m^2$)	Proportion (%)
0–5	Small	466	78.0	847.29	16.4
5–10	Middle	63	10.6	295.43	5.8
>10	Large	68	11.4	4146.86	77.8
Total		597	100	5289.58	100

4.2. Result of remote sensing investigation and evaluation of the outskirts forestlands

Forestland in the outskirts mainly refers to greenbelt or the greenbelt system surrounding the city. It has some effect of protection, resistance and adjustment to the urban ecological environment.

Based on the classification and features of images, results of remote sensing investigation of various forests are shown in Table 3 and Fig. 4.

At present, the average area of the forestlands is only 0.3 ha/person. Most large pieces of forestlands are scarce, and integrate protective systems of forest web and intercropping has not been formed yet. The species of forest and trees are also scarce. These are mostly forests to maintain water, soil and to support water source. The species of trees are mostly pine and cypress. Over 90% are middle or small aged forests.

Due to the frequent occurrence of artificial destruction, plant diseases and insect pests, the ecological and economic

Table 3
Areas and proportions of various forests in outskirts of Jinan City

Type of forest	Covering area (km^2)	Percent of the total forests
Protective forest	44.97	33.68
Intercrop forest	13.90	10.41
Economic forest	9.68	7.25
Sparse forest	10.16	7.61
Non-afforested forest	4.45	3.33
Forest web	44.88	33.61
Scenery forest	5.48	4.11
Total	133.52	100.0

benefit of forests cannot be fully developed. Furthermore, the function of protection of the forest is also low.

Most existing forests in Jinan are public ones, the economic effect of which is comparatively low. Peasants lack enthusiasm to manage them. Moreover, the remaining desolate hills suitable for reforestation are mostly distant and high ones. The reforestation is difficult and the management is not convenient. In addition, these places are mostly depressed areas, and the public cannot afford the fee for reforestation, therefore, the situation of desolate areas is hard to change. Some of the existent forests lying in the downtown area and the outskirts have been "nibbled", and some have returned to be desolate again.

5. Summary

By means of remote sensing, we completed detailed study of urban forests in Jinan, China. We mainly describe the present condition deficiency of the urban forests in Jinan. Effective suggestions and measures are advanced for the development of the urban forests in Jinan as follows:

(1) Increasing the number of the greenbelt corridors, creating sequential plane greenbelt

Streets and rivers are two main formats of belt corridors in cityscape. We should set up greenbelt along the roads and establish protective forest belts on sides of the rivers such as the Yellow River, Xiao Qing River and the Moat. Therefore, "Green Corridor" can be formed, connecting other green lands and formatting a sequential greenbelt. The integrate ecological effect can be developed.

(2) Developing three-dimensional green space, creating three-dimensional greenbelt

The urban green space oriented in the 21st century should develop towards three-dimensional green space, optimizing the urban foundation and developing three-dimensional greenbelts. For example, planning *Jasmininnm nudiflorum* and *Campsis grandiflora*, etc. along the newly-built elevated road can improve the landscape of the elevated road, and turn the "Grey-dragon" into a "Green corridor" in the air.

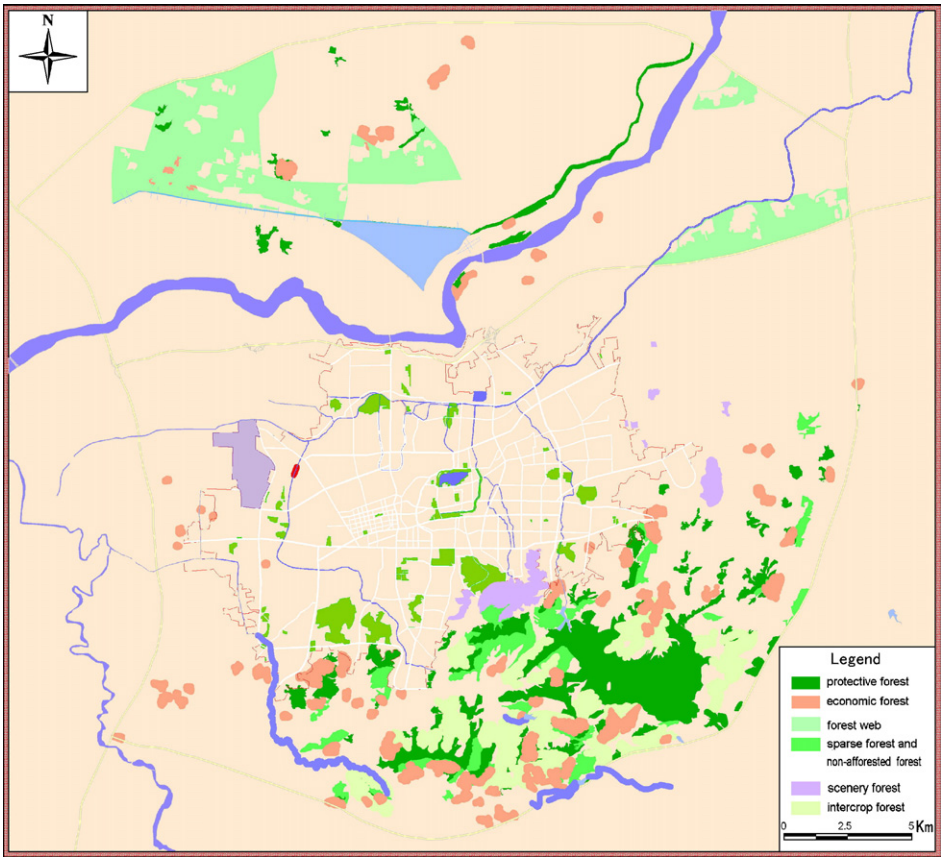

Fig. 4. Distribution of suburban forest in Jinan.

(3) Carefully selecting and comparing the tree species

The urban forest has various synthetic effects; therefore, we should synthetically consider all aspects. First, considering the species of the trees' ecological adaptability to the local climate and soil conditions, we focus on choosing the country species adapt to the natural conditions of Jinan City. Secondly, species' function in environmental protection should be emphasized, namely, we should focus on species' effects on resisting pollution, cleaning atmosphere and protecting the environment. Thirdly, we should choose species with certain ornamental value and economic worth.

(4) Programming reasonably and overall distribution

According to the principles of ecological benefit, we bring urban forest into the whole city's integral programming to form a system. In the downtown area, we focus on increasing the number of greenbelts on the street and enhancing green space level and standard of gardens, positively advocate three-dimension green space, vigorously plant trees along roads, greenbelts, and shade tree belts, especially work well for the planning, design and management work of the newly-built blocks and work hard to realize the greening of factories and courtyards. In suburbs, through performing the project of large environmental green space by stages, we tend to promote the development of the garden green space, increase the forest covering rate gradually and enhance the ecological protection function. Thus, the garden green space system gives priority to the south mountain forest and north forest around the Yellow River, and is complemented by forest belts along the river and road in the east to west direction.

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