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Current situation and development of Chinese urban forestry

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Key words: Ecosystem services, planning and construction, landscape spatial patterns, green GDP

SUMMARY

This paper introduces Chinese urban forestry research in terms of the concept, forest types, ecosystem services, spatial structure, planning and construction, assessment and management. Modern Chinese urban forest had a close relationship with traditional landscape architecture. Urban forest services had been quantified in some case cities, and determined by urban forest spatial patterns and internal structures. Based on landscape ecology and urban planning, urban forest spatial patterns have been analysed and planned rationally in some cities. However, studies on urban forestry generally lack long-term, continuous and systemic observations, as well as in-depth research on ecological processes and mechanisms. The development trends in urban forestry in China might include extensive application of ‘3S’ technology, research on the relationship between urban forest landscape spatial patterns and their ecological effects, economic assessment, ecological and economic benefits and studies on the negative effects of pollutants.

INTRODUCTION

Urban forestry has been described as: ‘a specialized branch of forestry that has as its objective the cultivation and management of trees for their present and potential contribution to the physiological, sociological and economic well-being of urban society. Inherent in this function is a comprehensive programme designed to educate the urban populace on the role of trees and related plants in the urban environment. In its broadest sense, urban forestry embraces a multi-managerial system that includes municipal watersheds, wildlife habitats, outdoor recreation opportunities, landscape design, recycling of municipal wastes, tree care in general, and the future production of wood fiber as raw material’ (Grey and Deneke 1986). Jorgensen (1970) defined urban forestry as not just city trees,

but rather tree management influenced and utilized by the urban population. This includes watershed and recreational areas serving the urban population. Urban forests contain all forest ecosystem services: carbon fixation and O₂ release, water storage, erosion control, transfer and exchange of materials and energy.

In China, urban forestry can be traced back to 1100 BC and the establishment of royal hunting grounds. Chinese traditional culture has had a profound impact on its modern urban forests and early research on the subject (Gao 1984; Shen 1992; Wang 1992; Wu 1993). Li (1993) considered urban forestry as a kind of multi-functional forestry, covering urban and suburban areas and including scenic, shelter, water conservation and economic

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forests, parks and conservation areas. Wu (1996) asserted that a city is a complex ecosystem composed of social, economic and natural sub-ecosystems that maintain ecological balance. Jiang (2000) considered urban forestry as an important part of modern urban construction that should be integrated into the landscape in the form of points, blocks, belts, networks and patches.

Cities are socio-economic–natural complex ecosystems in which urban forestry is essential and contributes to the efficient use of materials, with the coordinated development of society and nature. The urban forest landscape is an artificial green space in the urban areas, a semi-natural landscape in suburban areas and a close-to-nature forest landscape in outer suburban areas. Currently, Chinese urban forestry involves research on urban forest types, structure, functions, benefits, tree selection, distribution, planning, economic value, maintenance and management. In 2002, China implemented ‘the National Standard for Classification of Urban Green Space’, in which urban green land is classified into five major categories, 13 categories and 11 subcategories; however, for urban forest types, there is no official uniform standard.

FUNCTIONS OF URBAN FORESTS

Improving microclimate and alleviating urban heat island effects

An urban heat island (UHI) occurs when a metropolitan area is much warmer than its surroundings. Shade and transpiration from urban forests can significantly reduce air temperatures, increase humidity and regulate airflow. Satellite imagery and historical meteorological observations are used in many Chinese cities to examine the relationship between an UHI and green landscape spatial patterns. Studies in Beijing (Li *et al.* 2004; Tong *et al.* 2005) have shown that temperature alleviation is not significant when the green land cover is less than 37%, but when cover reaches 40% or 50%, the summer heat effect may be fundamentally reduced.

Purifying air and reducing bacteria

Trees effectively reduce air pollution by absorbing gaseous pollutants, primarily through their stomata, and retaining particulate pollutants on their leaf surfaces. Zhang *et al.* (1997) and Chen

et al. (2006) studied three types of green lands within residential areas of Beijing and found that trees with shrubs and grass have the highest dust reducing capacity, followed by shrubs and grass and then grass alone. Furthermore, they found that the leaf surface characters, tree canopy structure and branch density affected the capacity to improve air quality. The capacity for dust uptake was found to be in the order: deciduous broadleaf shrubs > evergreen broadleaf shrubs > hedges > evergreen broadleaf trees > deciduous broadleaf trees > coniferous trees > grass. Shao *et al.* (2004) studied the relationship between landscape patterns of urban green lands and air pollution in the central district of Yichang City and found that the greater the average area and the lower the fragmentation index of green land patches, the more effective green lands were in purifying the air.

Urban natural disaster prevention, reduction and refuge provision

China suffers frequent serious natural disasters, including earthquakes, landslides, debris flows, floods, droughts, typhoons and coastal erosion. Urban green lands can prevent or reduce the effects of disasters, as well as providing a refuge for urban residents in emergencies. Hong and Cui (1999) and Chen and Zhang (2006b) analysed this important function and prepared plans for the reconstruction of urban green lands after an earthquake in Tangshan City, Hebei Province, and the Yuan Dynasty City Wall Relic Park in Beijing.

Maintaining urban biodiversity

The rapid decline in biodiversity is a major global environmental problem. Biodiversity is directly related to human survival and sustainable development. However, urbanisation has destroyed local biota and intensified biodiversity destruction, especially when urban development is short-sighted and disorderly, leading to high levels of environmental pollution. Zhang (1999) and Liu (2006) suggested the following strategies for urban biodiversity conservation in urban forests: investigating and cataloging urban biodiversity to build long-term monitoring networks; making full use of native plants to simulate local climax communities, with multilayers of trees, shrubs, grasses and suitable foreign plants; establishing *in situ* and *ex situ*

conservation habitats for rare and endangered animals and plants, and domesticating dominant species in urban arboretums, parks and nurseries; and rational planning of urban forest and integration of urban–suburban green lands networks.

STRUCTURAL ANALYSIS OF URBAN FORESTS

Landscape structure

This involves remote sensing and GIS technology, based on calculating indices of patch density, fragmentation, dominance, evenness, diversity and connectivity. Liu *et al.* (2003a), Yang *et al.* (2006) and Guo *et al.* (2005) found a non-linear relationship between natural and social factors and landscape pattern changes.

Stand structure

Stand structure refers to spatial and temporal distribution patterns in a forest. Urban forest ecosystems are strongly influenced by human activities, and have their own characteristics in terms of physiology, species composition, population structure, dynamics and spatial patterns. Fu *et al.* (2000) found that the components and forest phase of Shanghai plant communities was zonal, although influenced by human activities. Similarly, He *et al.* (2003), studying species composition, type, structure and stratification in Shenyang Arboretum, concluded that it had formed a multi-generation and multi-layer, near-natural forest community. It is very important to select plants species with resistance and tolerance to the urban environment. Liu *et al.* (2003b) measured plant height, basal diameter, crown cover and growth rate as indices of pollution tolerance of 35 urban plant species growing near ceramic factories, and subsequently chose eight highly tolerant species, 17 medium-tolerant species and eight sensitive species to provide a reference for urban plant selection.

PLANNING AND CONSTRUCTION OF AN URBAN FOREST

Spatial distribution patterns

The total ecosystem services provided by an urban forest are determined by landscape spatial patterns

and internal structures when the green land cover is less than 40%. There are four major landscape distribution patterns (Che 2001):

1. **Encompassing.** The urban forest encircles the city, which limits urban sprawl and isolates the core city from surrounding satellite towns.
2. **Mosaic.** The urban forest spatially intersects cities and towns.
3. **Greenheart.** Smaller city forests develop surrounding a big 'greenheart' of urban forest.
4. **Belt-shape combined.** The urban forest connects cities through the urban long-axis so that they remain laterally open.

Urban forest networks

Peng (2003a) and Peng and Wang (2003) put forward the concept of a forest eco-network system for China (CFENS) in the form of criteria for forest spots, lines and surfaces. In China, urban green cover is so low that this network concept is highly suitable for cities. An urban forest eco-network system interacts with urban waters, farmland and other ecosystems to effectively improve the urban or regional environment; forming an optimal landscape pattern comprising different landscape elements that include urban water and roads networks that can provide a skeleton for the urban ecosystem. Networking forest and water systems was recommended in urban forest planning for the construction of a 6340-km² forest in Shanghai (Peng 2003b), and Changchun City in Jilin Province became the first such 'Forest city' in 1988.

Many Chinese metropolises have initiated urban forest planning and construction to: (1) create urban forest landscapes; (2) develop rural economic forests; (3) build ecological shelters; (4) improve networking of farmland and forest; (5) plant trees throughout cities; and (6) take comprehensive measures to form urban–rural integrated green landscapes and multi-layer, multi-function, multi-benefit urban forest patterns. Theoretical studies have focused mainly on the methods and guiding principles for urban forest planning, and on how to apply ecological planning methods combined with multi-functional and multi-objective planning (Yang and Xue 2006). Urban forests should provide specific ecological functions, such as high-tolerance to pollutants, or absorption of

a certain pollutant, as well as improving the environment for the inhabitants of cities.

A comprehensive evaluation index for urban forests

Zhang *et al.* (2001) built an evaluation index that includes: the stability of urban forest ecosystems, recreation, air purification and alleviating urban heat island effects. Zhu *et al.* (2003) suggested three levels and twelve indices for urban forests, consisting of structure, function and coordination to build an evaluation index system for Shanghai.

Research efforts should also be focused on understanding multi-disciplinary interactions and integrating these into plans and evaluation indices. Research on urban forest hydrology and effects of global climate change should be included in future studies. Understanding the overlap of urban forest and natural forest will provide a breakthrough for 'analysis of the forest rural-urban ecotone' (Zhu *et al.* 2001).

Management and administration of urban forests

1. Urban forest is a resource, so its management and administration must be founded on information and scientific data, including classifying and cataloging the forest, laboratory analysis and data storage of results leading to the production of final reports and plans.
2. Management measures include maintenance of urban plants, such as pruning, fertilisation, irrigation, transplantation, disease control, introduction and domestication of urban plants and protecting ancient and famous trees in cities.
3. Legislation for urban forestry. Construction and administration of an urban forest is a systematic project that must comply with corresponding laws or regulations. In China, such regulations include the *Urban Planning Act of PR China* and *Management Ordinances of Urban Afforestation*. Some local governments also adopt specific ordinances to protect local trees, such as the *Ordinances to protect ancient and famous trees* in Beijing. However, there are no laws or ordinances pertaining to maintenance or establishment of urban forests.

Existing relevant laws or ordinances are not detailed enough to guide specific work and the enforcement of laws is not rigid.

Reinforcing management and administration, establishing a strong law enforcement team, and enacting laws for the urban forest are presently urgent problems that need to be resolved.

PROBLEMS AND DEVELOPMENT TRENDS

Generally, urban forestry research in China is still at an early stage and many problems and research areas remain to be addressed, including:

1. Studies on urban forestry have largely focused on description (i.e. statistical analysis of experimental data), but generally lack in-depth study of the ecological processes, mechanisms or long-term continuous observation.
2. The urban forest is greatly affected by human activities and restricted by factors involving nature, society and the economy. Existing research lacks an integrated and systematic approach. Not enough has been done on the relationship between human interference and the driving forces for urban forest landscape pattern changes.
3. There is a lack of integration of different scales, methods and disciplines that could lead to better evaluation analysis of the landscape ecology and use of 3S technology.
4. Traditional green land evaluation focuses on quantitative indicators such as rate of greening, percentage of greenery, mean green space per person and public green space per person. This has led to the creation of 'marginal green lands' established just to satisfy mandatory indicators, regardless of real quality. Some evaluation indicators systems have been built but many such systems are too complicated for actual operation. It is urgent to establish a unified and operable urban forest comprehensive evaluation indicator system that covers ecological, structural, landscape and other factors, and reflects the urban forest structure, function, benefit and other issues. It is important to build up criteria grades, evaluation procedures and methods to

provide a scientific and rational quantitative basis and evaluation instrument for planning and construction of the urban forest.

5. Current urban forest ecological planning is specific to the urban master plan. However, this lacks integrated, systematic and regional viewpoints. The plan generally also lacks experimental design and empirical studies on the relationship between urban forest landscape patterns and ecological effects. Urban construction land is limited and ecosystem services of different types of green lands differ; thus, it is important to explore the relationship between form and functions to improve the ecological effects of green lands by their rational distribution in the limited areas available.

With the rise of computer capacity and 3S technology, studies on the urban forest have experienced some breakthroughs, from qualitative analysis to quantitative analysis, that will provide better data for urban eco-environment construction. Much of the information on urban forests, such as species composition, cover percentage, type, spatial distribution, health, age and community succession could be obtained quickly through physical inventories that use GIS and remote sensing. In the future, these studies will tend to use '3S' technology combined with databases to catalogue urban forests, construct models of urban forest ecosystems, plan urban forests rationally, evaluate benefits, monitor the status quo, simulate development trends and budget expenditure for the urban forest (Feng and Li 1999). A key issue is how to improve the ecological effects of green lands in limited urban lands through rational distribution. More research is needed on the processes and mechanisms governing urban forest ecosystem services. At the same time, by reinforcing studies on social functions, including human health, culture and education, landscape and aesthetics, tourism and human psychology, urban forests will be studied in a more integrated and systematic fashion.

Economic assessment of urban forest functions and the study of ecological benefit compensation show that urban forests not only have social and economic functions, but also provide a production base for wood, flowers, bonsai and other nurseries. Forests also promote tourism, drive tertiary

industries and increase value of surrounding real estate. It is necessary to build an integrated evaluation indicators system and assessment models to calculate the economic value of the urban forest and make 'green GDP' part of the national accounting system.

Urban forest can have negative effects if inappropriate species are introduced, such as foreign plants that may lead to serious ecological consequences, and may even harm urban residents. Biological invasion (Chen and Bao 2004; Li 2004a), flying seeds and catkins (Wang 2003), pollen pollution (Wang 2003; Liao 1991) and release of toxic gases (Benjamin *et al.* 1996) are a few examples of the negative effects. Correct understanding of such negative elements includes total pollution caused by plants, relative pollution impact of different species, the role of natural processes in mitigating or enhancing plant-caused pollution, and the impact of plant location and arrangement on plant-driven pollution.

CONCLUSIONS

The theoretical basis of urban forestry is vegetation physiology and ecology. Remote sensing and Geographical Information Systems serve as the primary vehicles for analysing available information. Landscape ecology and ecosystem ecology also serve as assessment tools. Other tools in urban planning, landscape architecture, economics, management and other disciplines should also be incorporated.

The practice of urban forestry in China has become an important means of improving the urban eco-environment and protecting biodiversity. Compared with Western urban forestry research, research in China has stressed distinct issues and concerns related to the Chinese landscape and culture. Looking forward, many new areas should be explored in order to develop a comprehensive understanding of the various positive and negative impacts of urban forests on their surroundings. With the goal of building a better society in China and elsewhere, broad international cooperation and exchanges will be important to improve research on urban forestry, to promote urban eco-environment construction and to ensure sustainable and healthy development of rapidly-growing cities in China.

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