Cities 26 (2009) 187–194

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Ecosystem services and valuation of urban forests in China

C.Y. Jim *, Wendy Y. Chen

Department of Geography, The University of Hong Kong, Pokfulam Road, Hong Kong

ARTICLE INFO

Article history:
Received 21 October 2008
Received in revised form 4 March 2009
Accepted 23 March 2009
Available online 17 May 2009

Keywords:
Urban forest
Ecosystem service
Economic value
Contingent valuation
Hedonic pricing
Recreation value
Amenity value
China

ABSTRACT

Urban forests are integral components of urban ecosystems, which could generate significant ecosystem services, such as offsetting carbon emission, removing air pollutants, regulating the microclimate, and recreation. These ecosystem services contribute to improving environmental quality, quality of life, and sustainable urban development. Despite a long history of inserting vegetation in human settlements in China, modern scientific study of this natural-cum-cultural resource did not start until the 1990s. Specifically, the identification and valuation of ecosystem services provided by urban forests are relatively new but fast growing research fields. This paper reviews studies on the major ecosystem services provided by urban forests in China, including microclimatic amelioration (mainly evapotranspiration-cooling effects), carbon dioxide sequestration, oxygen generation, removal of gaseous and particulate pollutants, recreational and amenity. Various valuation techniques have been applied, most of which are still at the embryonic stage. There are rooms to improve the research scope and methods. Some pertinent research gaps and implications on current and future development of urban forestry in China were distilled from the research findings.

Introduction

Urban greening in China, like in other places, has developed in tandem with the evolution of civilization and society. The innate desire to re-establish the severed links with nature in settlements, as expounded by the biophilia concept (Wilson, 1984), has been earnestly expressed. There is no unequivocal historical record on how and when landscape vegetation was first planted in Chinese settlements. It is believed that notable urban greening was initiated in royal gardens (Du et al., 1986) to symbolize the extension of imperial power on its subjects, and an attempt to find harmony between people and nature (Fan and Li, 2005). Throughout the feudal period, gardens were widely built by royal and aristocratic families as the integral components of private residences and palaces. Of all the royal gardens built in several millennia of Chinese history, the most prominent exemplar is the Summer Palace of the Qing Dynasty (1885–1894). Meanwhile, amenity plants were also commonly cultivated in temple grounds to satisfy religious objectives.

However, the development of urban forests for public use was a recent phenomenon in Chinese cities. With the influence of western urban greening concept during the semi-feudal and semi-colonial period (1840–1949), several big cities managed to convert old royal or private gardens to public use, such as the Zhongshan Park in Beijing (Zhao, 2000). After the establishment of the socialist government in 1949 in China, Mao's policy of "afforesting the motherland" laid the foundation of urban greening in cities. Landscaping offices were established at the municipal level to plant and manage urban greenery and green spaces. Adoption of the reform and open policy in 1978 has brought a host of new institutions and regulations to reinforce the planning, installation, management and conservation of urban green spaces (Jim and Liu, 2000). In the recent years, urban greening has attracted increasing attention and resources at different administrative levels. In conjunction with rapid urbanization and development of new cities and districts, new green areas have been created or preserved (Yu and Padua, 2007). The greening of compact Chinese cities demands special efforts and techniques that deviate from cities in western countries (Jim, 2004).

Despite the long history of urban greening in China, the modern study of urban forests was introduced into China after the 1990s (Wang, 1995; Li et al., 2005). Rapid urbanization since the implementation of opening-up and reform policy has generated massive urban sprawl into the surrounding countryside, infilling of intra-urban and peri-urban green fields, and a rapid increase in urban population. The associated environmental deterioration, ecosystem disturbance, and congested living condition have imposed pressures and constraints on the urban environment. The aggravating blights in cities have generated demands for urban greenery to abate the environmental problems and to improve the quality of urban life (Cai et al., 2004; Chen and Jim, 2008a,b). The strong desire to develop liveable and sustainable cities has set the stage for comprehensive study of urban forest in the country. In general, the

* Corresponding author. Tel.: +852 2859 7020; fax: +852 2559 8994.
E-mail address: hragjcy@hkucc.hku.hk (C.Y. Jim).

0264-2751/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cities.2009.03.003

study of urban forests in China includes three key themes: analysis of urban forest structure, assessment of their ecosystem services, and their planning and management. Urban forest structure provides basic information for further evaluation of functions, benefits and management (Kong and Nakagoshi, 2006). The ultimate purpose of urban forest study is to inform comprehensive planning and scientific management (Zhang and Yu, 2007).

Urban forests could generate significant ecosystem services, such as offsetting carbon emission (Jo, 2002), removing air pollutants, reducing noise, regulating the microclimate (Bolund and Hunhammar, 1999), recreation and amenity (Jim and Chen, 2006a). Collectively, they contribute to improving environmental quality, quality of life, and sustainable urban development (Miller, 1997; Jensen et al., 2000; Li and Wang, 2003; Chen and Jim, 2008a,b). The quantification and valuation of ecosystem services could permit direct comparison between alternative land use options, and facilitate cost-benefit analysis of related policies (McPherson et al., 1997; Tyrväinen and Miettinen, 2000).

This paper reviews studies on the multiple ecosystem services and economic values of urban forests in China. Thus far, there has been no clear delineation of the scope of ecosystem services provided by urban forests and no standardized methodology for evaluating their ecosystem services in China. We attempted to categorize various ecosystem services according to the system of the Millennium Ecosystem Assessment (Hassan et al., 2005). Publications in both international and Chinese journals related to urban forest research in China were consulted. Hong Kong and Macau, being special administrative regions of China with a different modern history, were not included in this review. The locations of the large Chinese cities in different regions included in this review are shown in Fig. 1. The Chinese currency *Renminbi* (RMB) has an official exchange rate of US$1 = RMB7.6 in May 2008.

Regulating services

Air quality regulation

Urban forests can make significant contributions to urban air quality. The removal of air pollutants, such as sulphur dioxide, nitrogen oxides, ozone, carbon monoxide and particulates, signifies an important ecosystem service. This function is particularly crucial in Chinese cities, where air quality is deteriorating at a fast pace due to rapid urbanization and industrialization (Chen, 2006). The quantification and valuation of this ecosystem service have attracted much attention in China.

The removal of sulphur dioxide and particulates by urban forests has been extensively studied. Consistently, they have been identified in urban air quality monitoring as the principal pollutants, mainly due to the use of fuels with high sulphur content (Wang et al., 2006). In the recent years, nitrogen oxides have emerged as an additional major air pollutant in many cities due to a rapid increase of private cars and inadequate road systems (Zhuang, 2003).

Empirical studies in western countries (e.g. McPherson et al., 1997) considered dry deposition as the main air pollutant removal mechanism. The pollutant flux was calculated as the product of deposition velocity and pollutant concentration. Most Chinese studies adopted a different approach. The capability of plants to remove air pollutants was estimated by measuring sulphur in different plant parts (e.g. Chen et al., 1998b; Fang, 2006). To quantify the

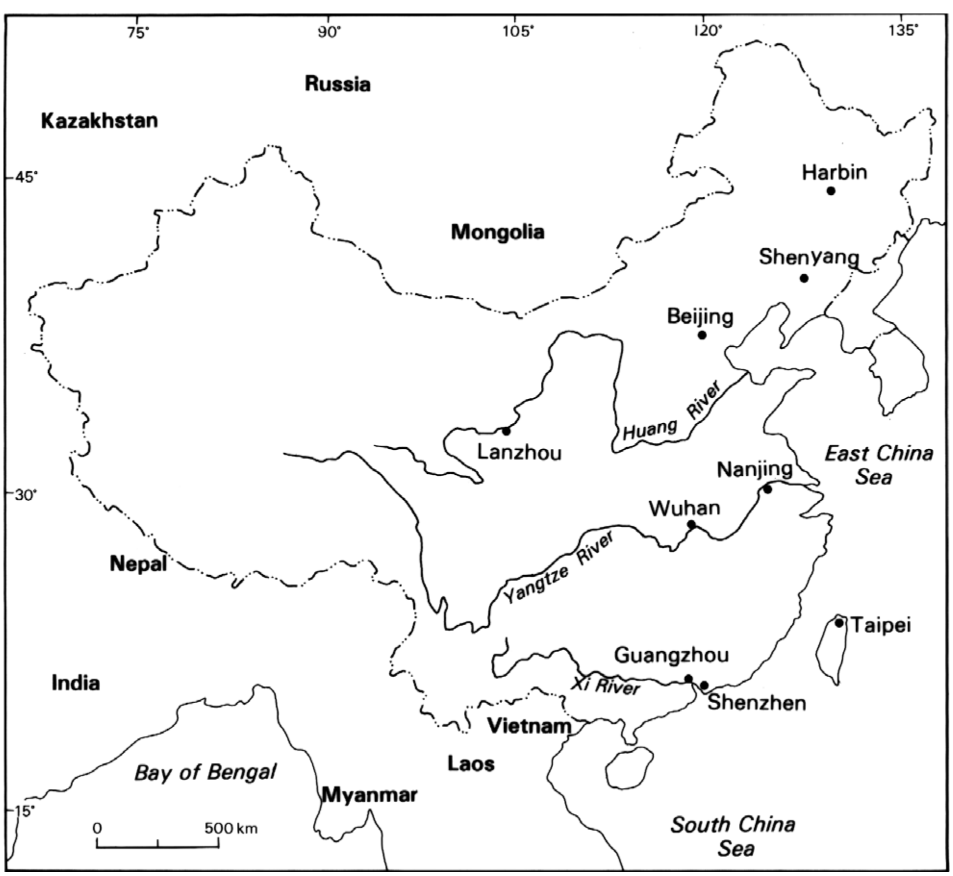

Fig. 1. The Chinese cities that have been subject to studies on ecosystem services and monetary values of urban forests.

monetary value of air pollutant removal by urban forests, two methods have been adopted in Chinese studies. The first is the marginal cost, which estimates the additional cost of producing a unit of air pollutant. The second is the replacement cost, which estimates the approximate cost of reducing pollutant emission using extant control techniques in industries, such as desulphurization and particulate precipitation (Chen, 2006).

Several studies have been attempted to valuate air pollutant removal by urban forests in China. They yielded varied results due to the adoption of different quantification and valuation approaches (Table 1). A Lanzhou (capital of Gansu province, in western arid and continental part of China) study found sulphur dioxide and particulate removal rates at, respectively, 0.171 and 10.9 t/ha/year (Zhang et al., 2006b). The removal capacity for the whole city was calculated by multiplying the area of urban forests (2789 ha) by these estimates. The monetary value of pollutant removal was RMB0.28 $\times$ 10^6/year for sulphur dioxide (based on replacement cost of RMB600/t), and RMB0.91 $\times$ 10^6/year for particulates (based on marginal cost of RMB30/t). The replacement cost is based on the fees levied on pollutant emission from industrial sources in Gansu province (Zhang et al., 2006b).

In a study of Beijing's urban forest, the removal capacity for sulphur dioxide was estimated by measuring sulphur accumulation in different plants, amounting to 2192.41 t/year (Leng et al., 2004). Applying the local marginal cost of RMB1200/t for sulphur dioxide (1999 price), the removal value was RMB2.5 $\times$ 10^6/year. For particulate removal, field data were collected on the deposition of particulates on plant leaves by Chen et al. (1998a). On average, 1.518 t/ha/year of particulates could be removed by urban forests in Beijing. By applying a marginal cost of RMB560/t, the monetary value of particulate removal was RMB17.1 $\times$ 10^6/year (Leng et al., 2004). The marginal cost is based on the fee levied on pollutant emission from industrial sources in Beijing.

Yang et al. (2005) conducted a more detailed study in Beijing, focusing on air pollution reduction by urban forests. They applied the urban forest effects model (UFORE) developed by the USDA Forest Service Northeastern Research Station (Nowak and Crane, 2000). Using local field data, trees could capture from the atmosphere 1261.4 t/year of total air pollutants (including 772.0 t of PM_{10}, 256.4 t of O_3, 132.3 t of NO_2, and 100.7 t of SO_2). In the same study, the air pollutant avoidance due to reduction in cooling energy consumption (evapotranspiration-effect) was 20,054.1 t/year, with CO_2 taking the largest share. A similar model was adopted to evaluate air quality improvement (CITYgreen software developed by American Forests, 2004). The value of air pollutant removal by urban forests in Shenyang (capital of Liaoning province in northeast China) with 19,944 trees reached US$16,318.21/year, including 1385.58 kg/year and US$9417.16/year for O_3; 430.27 kg/year and US$715.79/year for SO_2; 794.41 kg/year and US$599.50/year for NO_2; 159.07 kg/year and US$152.89/year for CO; and 1197.39 kg/year and US$5432.87/year for PM_{10} (He et al., 2003).

Uncertainties in the quantification methodology have been acknowledged, such as the application of models based on western urban forest studies without appropriate modifications to suit local conditions. For example, the replacement cost of air pollutant removal in China would be different from the US, because different technologies would be employed and labour and material costs are usually lower in China. Moreover, dry deposition velocity of each air pollutant on vegetation at the local scale is a crucial factor in quantifying air pollutant removal in a city. The direct adoption of the relevant parameters given in western models, which explicitly demands the acquisition of local data, would indicate possible inaccuracies of the findings.

In a recent study, Jim and Chen (2008) assessed the ecosystem service of air pollutant removal by urban trees in Guangzhou (capital of Guandong province in south subtropical area of China). The dry deposition process and the average dry deposition velocities based on the empirical studies were adopted. Trees in the built-up area of Guangzhou could remove 312.03 t/year of air pollutants, including 30.25 t/year of SO_2, 47.98 t/year of NO_2, and 233.79 t/year of total suspended particulates. The total benefits were valued at RMB90,000/year based on the marginal costs of air pollutants. Recreational open spaces contributed the most to air pollutant removal due to high tree cover. The results suggested that this ecosystem service could be maximized by planting more trees, diversifying tree species choice, and providing sound urban forest management.

The estimated air pollutant removal by urban forests varied amongst Chinese cities (Table 1), which might be attributed to: (1) different quantification methods and (2) different vegetation species which have different removal capabilities. In addition, the removed quantities in Chinese studies were much higher than overseas findings, which were estimated to range between 9.7 and 19.4 kg/ha land area, including all air pollutants considered such as CO, NO_2, SO_2, PM_{10} and O_3 (Nowak, 1994; Scott et al., 1998). Higher pollutant concentrations in Chinese cities could raise deposition rates (Scott et al., 1998) and contribute to greater removals. Moreover, western studies used dry deposition as the main removal mechanism by urban forests (Lovett, 1994; Nowak, 1994; Scott et al., 1998). Most Chinese studies adopted the pollutant accumulation in plant tissues (or the empirical results based on similar methods) to assess vegetation's capability to remove air pollutants. For instance, the amount of sulphur in a plant hints about the amount of SO_2 absorbed from the ambient atmosphere. The amount could be overestimated because air pollutants may not be the only source of materials accumulated in plants. Furthermore, the average removal capabilities given in western studies were calculated by dividing total removal amounts by total land area, whereas in Chinese studies the total urban forest areas were adopted.

Microclimate regulation

The influence of urban forests on local microclimate is multidimensional and complex, including modification of solar radiation, wind speed, air temperature, relative humidity, and terrestrial re-radiation (Grimmond et al., 1994; McPherson et al., 1997; Miller, 1997). Studies in western countries mainly focused on tree effects on cooling and heating energy saving at the local scale in low-density residential neighbourhoods, with an emphasis on shading provided by trees (e.g. Simpson, 1998). However, tree-shading effect in residential areas is negligible in Chinese cities, because almost all residences live in multi-storey buildings. The sheer bulk of high-rise and tightly packed buildings, many times of trees, would overwhelm tree-shading and related cooling effects. Thus the studies of urban forest impacts on microclimate in Chinese cities usually focused on the evapotranspiration effect at the city level (Table 2).

Evapotranspiration incurs the absorption of latent heat of vaporization from the ambient atmosphere to vaporize the water. The natural air-conditioning process would significantly decrease the ambient air temperature (Chen et al., 1998b; Cai et al., 2002; Ding, 2007; Wang et al., 2007). Meanwhile, the transfer of water to the atmosphere would raise the relative humidity in the vicinity of trees. Overall, urban forests could produce an "oasis effect" to render the urban environment, specifically its bioclimatic conditions, more comfortable.

In China, evapotranspiration from urban forests is usually estimated by measuring the latent heat consumption based on Yang's (1996) equations. The value of air temperature regulation can be calculated as cooling energy savings (Leng et al., 2004). Chen et al. (1998a) have quantified the evapotranspiration effects of

Table 1
The value of air quality regulation by urban forests in China.

City	Urban forest area or tree count		Air quality regulation and value				Source
			SO_2	Particulates	NO_2	O_3	
Lanzhou	2789 ha	Amount	0.171 t/ha/year (empirical result)	10.9 t/ha/year (empirical result)	NA	NA	Zhang et al. (2006b)
		Value	RMB0.28 × 10^6/year (replacement cost)	RMB0.91 × 10^6/year (marginal cost)	NA	NA	
Beijing	16,577 ha	Amount	2,192.41 t/year (sulphur accumulation in tissues)	1.518 t/ha/year (particulate deposition on plant leaves)	NA	NA	Leng et al. (2004)
		Value	RMB2.5 × 10^6/year (marginal cost)	RMB17.1 × 10^6/year (marginal cost)	NA	NA	
Beijing	2,383,000 trees	Amount	100.7 t/year (dry deposition)	772.0 t/year (dry deposition)	123.3 t/year (dry deposition)	256.4 t/year (dry deposition)	Yang et al. (2005)
		Value	NA	NA	NA	NA	
Guangzhou	7360 ha	Amount	42.62 t/year (dry deposition)	166.68 t/year (dry deposition)	40.93 t/year (dry deposition)	NA	Jim and Chen (2008)
		Value	RMB25,570/year (marginal cost)	RMB30,840/year (marginal cost)	RMB24,560 (marginal cost)	NA	

urban forests covering 16,577 ha in Beijing. They found that 3.42 × 10^6 t/day of water could be transpired into the ambient atmosphere to consume 84.1 × 10^6 kJ/day of heat energy. Of the different growth forms (tree, shrub, and herb), trees contributed the most to the thermal dissipation. Using these data, Leng et al. (2004) estimated the value of urban forest in Beijing for microclimate regulation at RMB934,579.2/day and RMB93.5 × 10^6/year. The calculation was based on the assumption that electrical power had to be consumed to achieve the same cooling effect in 100 summer days per annum.

Case studies were conducted to assess the varied effects of evapotranspiration and associated monetary value. For instance, in the warm-temperate part of China, the Wuhan Iron and Steel Company occupies a sprawling ground of 312.38 ha, about 20.20% of which is covered by an urban forest. The main tree species are *Cinnamomum camphora*, *Magnolia grandiflora*, and *Sabina chinensis*. The vegetation could absorb about 1.8 × 10^{12} kJ/year of heat energy through evapotranspiration. This cooling effect could be transformed into a monetary value of RMB163.3 × 10^6/year (Chen et al., 2006). In a study of Guangzhou's urban forests (7360 ha) in the humid subtropics, summer cooling effect of the urban forests was valued at RMB573.5 × 10^6/year, and contributed to an average saving of RMB12.5/year per home (Chen, 2006). Local meteorological conditions, inherent characteristics of urban forests (such as area, species composition, and biomass structure), and city surface albedo, might jointly regulate the cooling effect and hence monetary value in different Chinese cities. Based on the empirical data from western case studies, Zhang et al. (2006b) estimated the summer cooling value of 2789 ha of urban forests in Lanzhou at RMB6.8 × 10^6/year. The same study discussed the contribution to improving air temperature during winter, but the effect was not computed.

In several studies, the evapotranspiration-cooling evaluation focused on some common species. For example, in the urban forests of Harbin (Heilongjiang province in northeast cold temperate zone of China), the descending sequence of evapotranspiration rate was *Acer saccharum*, *Betula platyphylla*, *Forsythia suspensa*, *Lonicera japonica*, *Prunus maackii*, *Prunus triloba*, *Syringa oblate*, and *Ulmus pumila*. In addition, its urban forests contributed significantly to cooling in the peak summer months of July and August (Cai et al., 2002). Another recent study of urban forests in Nanyang city (Henan province in cool-temperate central China), assessed the heat consumed during evapotranspiration-cooling by several common species (Ding, 2007). The large tree *Platanus x hispanica* would absorb an average of 7008.53 kJ/m^2/day during summer (June to August) and lower air temperature by 0.47°C. For the small tree *Prunus triloba*, heat consumption and air cooling would be, respectively, 6559.52 kJ/m^2/day and 0.44°C. For the grass *Poa pratensis* (Kentucky Bluegrass) 8010.07 kJ/m^2/day and 0.53 °C were achieved. However, the study did not include economic valuation of the benefits.

Uncertainties exist in quantifying and valuating the ecosystem service of microclimate regulation. Firstly, at the micro level, different species and vegetation structures could affect evapotranspiration capacity (Yang, 1996; Chen, 1998; Cai et al., 2002; Ding, 2007) with impacts on microclimate. Currently, the evapotranspiration rates of only some common species have been measured, and data of most urban forest species are not available. Secondly, these case studies only include the summer cooling effect of evapotranspiration. Urban forests could also regulate microclimate by modifying incoming solar radiation and outgoing terrestrial radiation, shading, humidity, and wind direction and velocity. Few studies have been attempted in China on the processes and quantified benefits of these effects. Thirdly, local meteorological and aerodynamic conditions could regulate the contributions of urban forests to local microclimate (Oke, 1989). The area and shape of an urban forest and its hydrometeorological conditions could jointly influence the temperature below the green canopy and the surrounding built-up areas (Wang et al., 2006). Lastly, the monetary values did not consider real-world power demand for cooling, which could vary amongst individuals and different land uses. More specific and in-depth studies could minimize the uncertainty of quantification and valuation of this ecosystem service.

Western studies have documented the diverse results of energy savings due to urban forests. The potential annual savings (four shade trees per house, with simulation of the shading and evapotranspiration effects) could reach US$6.3 million in Baton Rouge, LA, US$12.8 million in Sacramento, CA, and US$1.5 million in Salt Lake City, UT (Konopacki and Akbari, 2000). Taha et al. (1997) found that urban trees could cool the city on the average by about 0.3–1.0°C, and total annual energy savings (shading and evapotranspiration) could attain US$10–35/100 m^2 of roof area of residential and commercial buildings. Akbari (2002) suggested that in Los Angeles, urban trees could potentially save about US$93 million of energy use per year and could reduce peak power demand by 0.9 GW. Local meteorological condition, the characteristics of urban forests (such as species composition, plant age, location to buildings), the albedo of city surface, and quantification method

Table 2
The value of climate regulation by urban forests in China.

City	Urban forest area or tree count	Quantification	Value	Source
Lanzhou	2789 ha	81.8 MJ/ha/year (empirical estimate)	RMB85.8 × 10^6/year (replacement cost)	Zhang et al. (2006a,b)
Beijing	16,577 ha	84.1 × 10^6 kJ/day (evapotranspiration rate)	RMB93.5 × 10^6/year (replacement cost)	Chen et al. (1998b), Leng et al. (2004)
Guangzhou	7360 ha	1024.1 × 106 kWh/year (evapotranspiration rate)	RMB573.5 × 10^6/year	Chen (2006)

(shading, evapotranspiration, or both), might contribute to the discrepancies in microclimate regulation value provided by urban forests between Chinese and overseas studies.

Water regulation

Only a couple of studies examined the ecosystem service of water regulation provided by urban forests in Chinese cities. In these studies, the CITYgreen software has been applied, in which an empirical model (Stormwater Runoff Program developed by the USDA Natural Resources Conservation Service) estimated runoff volume as well as percent changes at peak flow. For example, an assessment of an urban greenbelt, including agricultural land, was conducted in Hangzhou city (capital of Zhejiang province). In 10 years (1994–2004), the total value of its ecosystem services increased by RMB168 × 10^6, including runoff reduction, air pollutant removal, carbon sequestration and storage. Specifically, the value of water regulation of retaining 4.38 × 10^6 m^3 storm water was estimated at RMB0.47 × 10^9 in 2004. The ecosystem services were enhanced despite 20.4% reduction in urban forest area (from 32,889.9 ha in 1994 to 26,176.9 ha in 2004) (Zhang et al., 2006a). The value improvement was attributed to the conversion of agricultural land to urban vegetated land, which was endowed with a complex vegetation structure of high leaf area (average leaf area index was 1.3 for agricultural land and 8.9 for urban forests). However, the opportunity costs of this land use conversion were overlooked in this study, and its valuation results would denote rather crude estimates.

A recent Nanjing (capital of Jiangsu province) study offered some refinements in research methods. Local precipitation and land cover data were used to build the database to compute the value of runoff reduction using CITYgreen software (Peng et al., 2007). The cost of reservoir construction in China was employed in the calculation, at RMB1.00/m^3 of water storage capacity. The value of runoff reduction was estimated at RMB3.44 × 10^6/year. Due to variations in vegetation coverage, the ecosystem service of water regulation changed with land use in a descending sequence: green areas > public facilities > residential > transportation > industrial > municipal infrastructure.

Several assessments of water regulation valuation (mainly rainwater retention) could be found on the website of American Forests (www.americanforests.org). For example, a CITYgreen analysis in Metropolitan Washington, DC, found that the existing 46% tree canopy cover could reduce the need for retention structures by 949 million ft^3 (26.88 million m^3), valued at $4.7 billion per 20-year construction cycle (based on a US$5/$ft^3$ construction cost). Using a numerical interception model that calculated rainwater intercepted by trees, McPherson et al. (1999) estimated that street and park trees of Modesto, CA, could reduce annual runoff by around 292 million m^3 with an implied value of US$0.61 million (according to the cost of retention and detention basins at US$2.07/$m^3$). In China, the ecosystem service of water regulation has been largely overlooked. The application of western models has generated rough estimates that demand tailor-made interception models that encompass the hydrological conditions of Chinese urban catchments, and the refinement of parameters in western models to fit the Chinese urban context.

Cultural services

Urban forests could provide various cultural services, such as recreation, aesthetic value, educational value, sense of place, religious value, cultural heritage value (Dwyer et al., 1991). Only several recent studies investigated the recreation and amenity values of urban forests in China. The residents of Guangzhou city were found to be highly active in using urban forests for recreation and amenity purposes (Jim and Chen, 2006a). Over half of the respondents to a questionnaire survey stated visiting the urban forests more often than two to three times per week. Relaxation, quietude, nature appreciation, physical exercise, and aesthetic enjoyment were ranked as important reasons for using urban forests. Applying the contingent valuation method (in a questionnaire survey respondents were asked directly about their willingness-to-pay for the provision of recreation opportunities and amenities by urban forests in Guangzhou), the value of recreational opportunities and amenities attained RMB547.09 × 10^6/year. Only income level had a significant positive influence on their willingness-to-pay for this ecosystem service (Jim and Chen, 2006b). A survey of urban park visitors in Mianyang city (Sichuan province) indicated that urban forests served to relieve mental stress and fatigue and improve social interactions, but the value was not quantified (Tan and Zhao, 2007).

In addition to contingent valuation, the hedonic pricing method (estimating the value of ecosystem services by analyzing the response of housing price to amenity characteristics) was applied to assess the value of the intangible ecosystem service of recreation and amenity. The transaction data of residential properties in the emerging housing market in Chinese cities were gleaned to conduct the computations (Jim and Chen, 2008). In the old town centre of Guangzhou, the housing price would decrease by 6.6% with doubling in distance to the nearest urban park. A view of urban forests would increase housing price by 8.6% in urban areas (Jim and Chen, 2007). Residents were willing to pay a premium for homes with pleasant views of and easy access to nature.

In a Jinan study (capital of Shandong province), GIS and landscape metrics were used to determine the hedonic pricing model variables (Kong et al., 2007). The results confirmed that proximity to urban forests would exert a positive amenity effect on housing price. The value was influenced by urban forest size, distance to scenic sites, and proportion of urban forest area in a neighbourhood.

In Athens, GA, Anderson and Cordell (1988) found that a large front yard tree could improve the selling price of a house by US$336. Using this data, it was estimated that the annual value of aesthetics and other benefits (not specified, but reflected by the increment of property values) provided by street and park trees in Modesto, CA, was US$1.45 million, 95% of which was attributed to street trees (McPherson et al., 1999). Another case study assessed the amenity value of urban forests in Joensuu, Finland, using contingent valuation method. It was found that the annual amenity value was 3.81 million FIM (about US$0.8 million), and the mean willingness-to-pay ranged between 126 and 206 FIM (about US$26.7–43.6) depending on the household location (Tyrväinen and Väänänen, 1998). Dissimilar results could be found between Chinese studies and western studies that dealt with assessment of recreation and amenity value of urban forests, which could be explained by differences in urban forest characteristics and cultural background, with a bearing on perception and valuation of urban forests (Jim and Chen, 2006b).

Supporting services

Amongst various supporting services, only photosynthesis was considered within the scope of urban ecosystem (several cases are given in Table 3). It is widely acknowledged that vegetation plays an important role in the balance of carbon dioxide and oxygen in the urban atmosphere by sequestrating carbon dioxide and generating oxygen in the course of photosynthesis (Yang, 1996; Wu and Su, 2002). The capacity of urban forests in sequestering carbon dioxide and releasing oxygen is closely related to photosynthetic and respiration rate (Li et al., 2002; Chen, 2006). The marginal cost method is usually employed to valuate this ecosystem service. The Sweden government suggested a carbon tax at about RMB339.8/t (US$150/t) of carbon emission. This overseas benchmark was used because similar regulations on taxing carbon emission were unavailable in China. Although the application of this carbon tax seems to be arbitrary, because there are thus far no similar policies concerning the emission reduction in China (China was included in the Kyoto Protocol in 1998, but the national efforts and policies are still lagging behind), it is possible to derive some assessment that could be comparable in an international framework. Another approach enlisted the afforestation cost in China, which on average is equivalent to RMB273.3/t for carbon dioxide sequestration and RMB369.7/t for oxygen release (Hou, 1994). In several studies, the cost of producing oxygen through the industrial process was also adopted (Wu and Su, 2002), but no national standard is available.

Several methods were commonly applied to measure photosynthetic capacity, including half leaf method, analytical method of growth, quantitative method of oxygen density, and quantitative method of carbon dioxide absorption. Yang (1996) used a special meter to collect field data on photosynthesis and respiration capacity of eight common urban tree species in Guangzhou. The results indicated that the leaf area index was an important factor in the dynamics of carbon dioxide and oxygen. Plants with high leaf area index and high photosynthetic rate would contribute more to oxygen production and carbon dioxide fixation. *Aleurites moluccana* could release oxygen at 66.1 g/m^2/day and capture carbon dioxide at 90.6 g/m^2/day. For *Nerium indicum*, the respective results were only 7.6 and 10.3 g/m^2/day. The study did not include an estimate of the monetary values.

More detailed findings were obtained in a Beijing case study (Chen et al., 1998a). The photosynthetic rates of 65 common tree species were measured. Regression models were constructed to calculate carbon dioxide sequestration and oxygen generation. It was concluded that the urban forests in Beijing could release oxygen at 23,000 t/day and sequester carbon dioxide at 33,000 t/day. The value of this ecosystem service attained RMB2.62 $\times$ 10^9/year, of which RMB1.44 $\times$ 10^9/year was attributed to carbon dioxide sequestration (applying the Sweden carbon tax), and RMB1.18 $\times$ 10^9/year to oxygen release (applying the industrial production cost proposed by Leng et al., 2004).

Recently, the photosynthesis meter (LI-COR model LI-6400) has been widely used in China to collect data to calculate photosynthesis and related parameters. For example, Cai et al. (2002) measured several common species in the urban forests of Harbin (Heilongjiang province). They computed the amount of carbon sequestration and oxygen release, which varied by species and season. Usually, trees could contribute more than shrub and herb species. The effect would reach its peak in August, although sometimes excessively high temperature might dampen photosynthetic rate.

Similar outcomes were found in another case study of the urban forests in the transportation grounds of Dalian (Liaoning province) (Lu et al., 2006). The results indicated seasonal variations in photosynthetic rate of summer > autumn > spring. In addition, species with high capacity to trap particulates, such as *Sophora japonica*, *Eucommia ulmoides* and *Euonymus japonicus*, demonstrated reduced photosynthetic rate, which could be attributed to the negative effect of leaf-surface particulate deposition on sunlight absorption and stomata functions.

Biomass analysis based on the empirical data could also yield data on carbon dioxide and oxygen exchanges of urban forests. Wang et al. (2005) estimated the ecological benefits of the urban forests in Lianhuashan Park, Shenzhen city (Guangdong province). The total site area of 154.74 ha contains several dominant exotic trees, namely *Acacia confusa*, *Eucalyptus citriodora* and *Eucalyptus camaldulensis.* The photosynthetic rate, measured in the field, was used to calculate carbon dioxide sequestration and oxygen release. About 33,600 t/year of carbon dioxide could be sequestered and 24,300 t/year of oxygen could be released. The amount varied by vegetation communities. Based on field data of urban forests (5763 ha) in Guangzhou city, together with the empirical data of subtropical forests, Guan et al. (1998) found the total biomass and net primary production to be 392,495 t and 64,948 t/year, respectively. Moreover, the total carbon storage in the urban forests was 184,983 t, and 29,165 t/year of carbon would be sequestered. Using these data, Chen (2006) found the annual carbon sequestration across Guangzhou to be about 1.7 t/ha. The total carbon dioxide–oxygen value in Guangzhou, based on Chinese afforestation cost, was RMB78.5 $\times$ 10^6/year, of which RMB39.6 $\times$ 10^6/year was

Table 3
The value of photosynthetic capability of urban forests in China.

City	Urban forest area or tree count		O_2 release	CO_2 sequestration	Source
Lanzhou	2789 ha	Amount	12 t/ha/year (empirical result)	0.9 t/ha/day (empirical result)	Zhang et al. (2006b)
		Value	RMB13.38 $\times$ 10^6/year (replacement cost)	RMB0.3 $\times$ 10^9/year (Sweden carbon tax)	
Beijing	16,577 ha	Amount	23,000 t/day (photosynthetic capability)	33,000 t/day (photosynthetic capability)	Leng et al. (2004)
		Value	RMB1.18 $\times$ 10^9/year (industrial production cost)	RMB1.44 $\times$ 10^9/year (Sweden carbon tax)	
Guangzhou	7360 ha	Amount	13.4 t/ha/year (biomass estimate)	5.4 t/ha/year (biomass estimate)	Chen (2006)
		Value	RMB38.9'10^6/year (Chinese afforestation cost)	RMB39.6 $\times$ 10^6/year (Chinese afforestation cost)	

carbon dioxide sequestration, and RMB38.9 $\times$ 10^6/year oxygen release.

Different estimates could be found in western studies. For example, based on biomass equation of species, urban trees in the USA currently store an estimate of 700 $\times$ 10^6 t of carbon (at US$14,300 million value) with a gross carbon sequestration rate of 22.8 $\times$ 10^6 t C/year (at $460 million/year) (Nowak and Crane, 2002). The discrepancies in the findings of various studies were related to species composition, plant age, health condition and physiological characteristics (Nowak and Crane, 2002). The results of Chinese studies represented approximations of the value of supporting service (only photosynthesis) offered by urban forests. The emission of CO_2 due to urban forest management (such as fossil fuels used in planting, maintenance, and vegetation removal) was always overlooked. In addition, indirect CO_2 reduction due to summer cooling energy saving (avoidance of CO_2 emission from power plants due to the contribution of urban forests to reduction of air-conditioning energy use) was not considered. Although CO_2 is a dominant greenhouse gas, thus far there are no concrete policies to reduce its emission in China. The case studies in the Chinese context suggested some pioneering efforts, which could provide useful information for policy making and serve as the basis and stimulus for more elaborate analysis.

Conclusion

Scientific understanding of urban forest (variously labelled urban green space, urban tree, and urban green system) benefits to people in China has expanded in recent years. A review of the state of the present state of knowledge and related emphasis and mindset could allow a timely introspection, rationalize the use of tight resources, and throw light on future growth directions. Several critical issues could be identified from this review of the identification and assessment of ecosystem services generated by urban forests in China.

Firstly, there are no widely accepted methods for quantification and valuation of the ecosystem services offered by urban forests. Given the disparities in the findings across the studies of different scopes and methods, more research could be conducted on the critical issues of valuation, including: (1) evaluation of the high-level ecosystem services provided by urban forests, such as landscape enhancement, contribution to education, biodiversity conservation, wildlife habitat, erosion control, catchment protection for urban water supplies, and productive use or safe disposal of urban wastes; (2) enhancement of the accuracy of both quantification and valuation of ecosystem services generated by urban forests, for instance by improvement and standardization of data collection and analysis methods; existing information on urban forests in China is often confined to total land area of green covers, with meagre in-depth data on high-level attributers such as urban forest structure, species composition, species diversity, and specific ecosystem services of individual species; and (3) benefit transfer across Chinese and overseas cities, using economic valuation from previous studies to assess the value of ecosystem services at a particular site; such application of knowledge would be important when time and funding are inadequate to perform primary studies.

Secondly, even though the Chinese case studies have generated some rough estimates, they could serve as a starting point for deeper understanding of urban forests from different viewpoints. The approach could straddle ecological and economic realms, to permit integration of urban forests into local or national sustainable development and analysis.

Thirdly, the application of the research findings could be expanded. Only a few studies offered a clarification of the economic value of ecosystem services as part of welfare estimates (locally or nationally), and suggestions to allocate natural resources to maximize benefits. In China, inadequate financial support has imposed a chronic constraint on urban forest development, which could be partly attributed to the poor understanding of their economic benefits (Liu et al., 2004). Deeper comprehension of their ecosystem services could provide plausible information for benefit-cost analysis of related projects (McPherson et al., 1999; Chen and Jim, 2008a,b), and help justifying and augmenting municipal investment in the green infrastructure (McPherson et al., 1997; Li et al., 2005).

Finally, despite the accumulation of scientific evidence and findings, relevant policies and management practices are still lagging notably behind the knowledge front. Both researchers and practitioners could make efforts to manifest the value of urban forests, and to stress the mutually beneficial interactions between human society and nature. In the face of rapid and sometimes rampant if not unbridled urban growth in China, the quantity and quality of urban forests could be advertently or inadvertently suppressed or sacrificed. The chance to use urban forests to make hundreds of Chinese cities more liveable and sustainable and many millions of residents happier and healthier is too precious to be squandered. Thorough understanding of their ecosystem services and economic values presents a clinching initial step in the right direction.

Acknowledgement

We would like to thank the Seed Funding for Basic Research of our university for research grant support in connection with the project on cost-benefit analysis of urban greening in Chinese cities.

References

Akbari, H (2002) Shade trees reduce building energy use and CO_2 emissions from power plants. *Environmental Pollution* **116**, S119–S126.

American Forests (2004) *CITYgreen for ArcGIS: Calculating the Value of Nature*. American Forests, Washington, DC.

Anderson, L M and Cordell, H K (1988) Influence of trees on property values in Athens, Georgia (USA): a survey based on actual sales prices. *Landscape and Urban Planning* **15**, 153–164.

Bolund, P and Hunhammar, S (1999) Ecosystem services in urban areas. *Ecological Economics* **29**, 293–301.

Cai, C, Peng, Z and Wang, C (2004) The ecological benefit of urban forest and trees and its value. *World Forestry Research* **17**(3), 17–20 (in Chinese).

Cai, Y, Zhu, N and Han, H (2002) Photosynthesis and transpiration of urban tree species in Harbin. In *Advances in Urban Forest Ecology*, X He and Z Ning (eds.), pp. 186–194. China Forestry Publishing House, Beijing (in Chinese).

Chen, F, Zhou, Z, Xiao, R, Wang, P, Li, H and Guo, E (2006) Estimation of ecosystem services of urban green-land in the workshop area of the Wuhan Iron and Steel Company. *Acta Ecologica Sinica* **26**(7), 2229–2236 (in Chinese).

Chen, W Y (2006) *Assessing the Services and Value of Green Spaces in Urban Ecosystem: A Case of Guangzhou City*. PhD Thesis, University of Hong Kong, Hong Kong.

Chen, W Y and Jim, C Y (2008a) Assessment and valuation of the ecosystem services provided by urban forests. In *Ecology Planning and Management of Urban Forests: International Perspectives*, M M Carreiro, Y C Song and J G Wu (eds.), pp. 53–83. Springer Verlag, New York.

Chen, W Y and Jim, C Y (2008b) Cost-benefit analysis of the leisure value of urban greening in the new Chinese city of Zhuhai. *Cities* **25**, 298–309.

Chen, Z (1998) The analysis of current composition of urban forests in Beijing. *Journal of Chinese Landscape Architecture* **14**(1), 58–60 (in Chinese).

Chen, Z, Su, X, Liu, S, Gu, R and Li, Y (1998a) A study of ecological benefits of urban forests in Beijing (2). *Journal of Chinese Landscape Architecture* **14**(2), 51–53 (in Chinese).

Chen, Z, Su, X, Liu, S and Zhang, X (1998b) A study of ecological benefits of urban forests in Beijing (3). *Journal of Chinese Landscape Architecture* **14**(3), 53–56 (in Chinese).

Ding, X (2007) Ecological effects of the main plant species in urban forest. *Journal of Central South University of Forestry and Technology* **27**(4), 142–146 (in Chinese).

Du, R J, Li, E S and Liu, G P (eds.) (1986) *Design of Gardens and Parks*. Construction Industry Press of China, Beijing (in Chinese).

Dwyer, J F, Schroeder, H W and Gobster, P H (1991) The significance of urban trees and forests: towards a deeper understanding of values. *Journal of Arboriculture* **17**(10), 276–284.

Fan, B and Li, Z (2005) Construction of urban forest and inhabited environment in history of China. *Journal of Chinese Urban Forestry* **3**(1), 57–61 (in Chinese).

Fang, Y (2006) *A Study of Urban Forests' Ecological and Environmental Functions*. PhD Thesis, Nanjing Forestry University, Nanjing, China (in Chinese).
Grimmond, S, Souch, C, Grant, R and Heisler, G (1994) Local scale energy and water exchange in a Chicago neighborhood. In *Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project*, E G McPherson, D J Nowak and R A Rowntree (eds.). US Department of Agriculture, Forest Service, General Technical Report NE-186, Radnor, PA, pp. 41–62.
Guan, D, Chen, Y and Huang, F (1998) The storage and distribution of carbon in urban vegetation and its role in balance of carbon and oxygen in Guangzhou. *China Environmental Science* **18**(5), 437–441 (in Chinese).
Hassan, R, Scholes, R and Ash, N (eds.) (2005) *Ecosystems and Human Well-being: Current State and Trends. Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment*, Vol. 1. Island Press, Washington.
He, X, Hu, Z, Jin, Y and Chen, W (2003) The structure of urban forest in Shenyang city and their ecological benefits. *Journal of Chinese Urban Forestry* **1**(3), 25–32 (in Chinese).
Hou, Y (1994) *Study on Forest Resource Accounting of China*. Chinese Forestry Press, Beijing (in Chinese).
Jensen, M B, Persson, B, Guldager, S, Reeh, H and Nilsson, K (2000) Green structure and sustainability: developing a tool for local planning. *Landscape and Urban Planning* **52**, 117–133.
Jim, C Y (2004) Green space preservation and allocation for sustainable greening in compact cities. *Cities* **21**, 311–320.
Jim, C Y and Chen, W Y (2006a) Recreation-amenity use and contingent valuation of urban green spaces in Guangzhou, China. *Landscape and Urban Planning* **75**, 81–96.
Jim, C Y and Chen, W Y (2006b) Perception and attitude of residents towards urban green spaces in Guangzhou (China). *Environmental Management* **38**, 338–349.
Jim, C Y and Chen, W Y (2007) Consumption preferences and environmental externalities: A hedonic analysis of the housing market in Guangzhou (China). *Geoforum* **38**, 414–431.
Jim, C Y and Chen, W Y (2008) Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou. *Journal of Environmental Management* **88**, 665–676.
Jim, C Y and Liu, H H T (2000) Statutory measures for the protection and enhancement of the urban forest in Guangzhou city, China. *Forestry* **73**, 311–329.
Jo, H K (2002) Impacts of urban greenspace on offsetting carbon emissions for middle Korea. *Journal of Environmental Management* **64**, 115–126.
Kong, F and Nakagoshi, N (2006) Spatial–temporal gradient analysis of urban green spaces in Jinan, China. *Landscape and Urban Planning* **78**, 147–164.
Kong, F, Yin, H and Nakagoshi, N (2007) Using GIS and landscape metrics in the hedonic price modeling of the amenity value of urban green space: a case study in Jinan city, China. *Landscape and Urban Planning* **79**, 240–252.
Konopacki, S and Akbari, H (2000) Energy savings calculation for urban heat island mitigation strategies in Baton Rouge, Sacramento, and Salt Lake City. Proceedings of the 2000 ACRRR Summer Study on Energy Efficiency in Buildings, Vol. 9, August 2000, Pacific Grove, CA, pp. 215–226.
Leng, P, Yang, X, Su, F and Wu, B (2004) Economic valuation of urban greenspace ecological benefits in Beijing city. *Journal of Beijing Agricultural College* **19**(4), 25–28 (in Chinese).
Li, F and Wang, R (2003) Evaluation, planning and prediction of ecosystem services of urban green space: a case study of Yangzhou City. *Acta Ecologica Sinica* **23**(9), 1929–1936.
Li, F, Wang, R, Liu, X and Zhang, X (2005) Urban forest in China: development patterns, influencing factors and research prospects. *International Journal of Sustainable Development and World Ecology* **12**, 197–204.
Li, H, He, X, Chen, W, Xu, W, Zhu, W and Ning, Z (2002) Current status and future outlook of urban forestry research in China. In *Advances in Urban Forest Ecology*, X He and Z Ning (eds.), pp. 75–83. China Forestry Publishing House, Beijing.
Liu, C, Shen, X, Zhou, P, Che, S, Zhang, Y and Shen, G (2004) Urban forestry in China: status and prospects. *UA-Magazine*, 15–17.
Lovett, G M (1994) Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. *Ecological Application* **4**, 629–650.
Lu, G, Yin, Z, Gu, J, Meng, D, Wu, H and Li, Y (2006) A research on the function of fixing carbon and releasing oxygen of afforestation trees along the main road in Dalian city. *Journal of Agricultural University of Hebei* **29**(6), 49–51 (in Chinese).
McPherson, E G, Nowak, D, Heisler, G, Grimmpnd, S, Souch, C, Grant, R and Rowntree, R (1997) Quantifying urban forest structure, function, and value: the Chicago urban forest project. *Urban Ecosystems* **1**, 49–61.
McPherson, E G, Simpson, J R, Peper, P J and Xiao, Q (1999) Benefit-cost analysis of Modesto's municipal urban forest. *Journal of Arboriculture* **25**, 235–248.
Miller, R W (1997) *Urban Forestry: Planning and Managing Urban Green Spaces*, 2nd ed. Prentice Hall, Upper Saddle River, NJ.
Nowak, DJ (1994) Air pollution removal by Chicago's urban forest. In *Chicago's Urban Forest Ecosystems: Results of the Chicago Urban Forest Climate Project*, E G McPherson, D J Nowak and R A Rowntree (eds.), pp. 63–81. General Technical Report NE-186. US Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN.
Nowak, D J and Crane, D E (2000) The urban forest effects (UFORE) model: quantifying urban forest structure and functions. In *Proceedings Integrated Tools for Natural Resources Inventories in the 21st Century*, M Hansen and T Burk (eds.), pp. 714–720. IUFRO Conference, 16–20 August 1998, Boise, ID. General Technical Report NC-212, US Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN.
Nowak, D J and Crane, D E (2002) Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution* **116**, 381–389.
Oke, T R (1989) The micrometeorology of urban forest. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences* **324**, 335–348.
Peng, L, Chen, S, Liu, Y and Wang, J (2007) Application of CITYgreen model in benefit assessment of Nanjing greenbelt in carbon fixation and runoff reduction. *Chinese Journal of Applied Ecology* **18**(6), 1293–1298 (in Chinese).
Scott, K L, McPherson, E G and Simpson, J R (1998) Air pollutant uptake by Sacramento's urban forest. *Journal of Arboriculture* **24**, 224–233.
Simpson, J R (1998) Urban forest impacts on regional cooling and heating energy use: Sacramento county case study. *Journal of Arboriculture* **24**, 201–214.
Taha, H, Douglas, S and Haney, J (1997) Mesoscale meteorological and air quality impacts of increased urban albedo and vegetation. *Energy and Buildings* **25**, 169–177.
Tan, S and Zhao, W (2007) Social and psychological benefit of urban green spaces. *Journal of Chongqing Jianzhu University* **29**, 6–10 (in Chinese).
Tyrväinen, L and Väänänen, H (1998) The economic value of urban forest amenities: an application of the contingent valuation method. *Landscape and Urban Planning* **43**, 105–118.
Tyrväinen, L and Miettinen, A (2000) Property prices and urban forest amenities. *Journal of Environmental Economics and Management* **39**, 205–223.
Wang, M (1995) The research and development of urban forestry. *Scientia Silvae Sinicae* **31**, 460–466 (in Chinese).
Wang, X, Hu, Y, Liu, X, Gao, F and Zhu, Q (2007) Microclimate modification of urban grassland in Beijing. *Journal of Guangxi Normal University (Natural Science Edition)* **25**(3), 23–27 (in Chinese).
Wang, X, Li, Z, Jiang, X and Liao, W (2005) Quantitative evaluation on the ecological benefit of public park green space. *Journal of Plant Resource and Environment* **14**(4), 42–45 (in Chinese).
Wang, X, Wu, R, Zhang, H and Wang, S (2006) Report of Ecological Environmental Issues during Urbanization in China. Jiangsu People Publishing, Nanjing, China, (in Chinese).
Wilson, E O (1984) *Biophilia: The Human Bond with Other Species*. Harvard University Press, Cambridge, MA.
Wu, Y and Su, Z (2002) Present state of Chinese city green areas and estimation of its value in ecology and economy. *Journal of Sichuan Teachers College (Natural Science)* **23**(2), 184–188 (in Chinese).
Yang, J, McBride, J, Zhou, J and Sun, Z (2005) The urban forest in Beijing and its role in air pollution reduction. *Urban Forestry and Urban Greening* **3**, 65–78.
Yang, S (1996) *Urban Ecology*. Science Press, Beijing (in Chinese).
Yu, K and Padua, M G (2007) China's cosmetic cities: urban fever and superficiality. *Landscape Research* **32**, 255–272.
Zhang, K, Zhang, J, Chen, Y and Zhu, Y (2006a) Urban greenbelt eco-service value of Hangzhou city under effects of land use change: an evaluation with CITYgreen model. *Chinese Journal of Applied Ecology* **17**(10), 1918–1922 (in Chinese).
Zhang, W, Zhang, F, Yan, Z and Zhang, Z (2006b) Initial analysis on the ecological service value of the greening land in Lanzhou city. *Pratacultural Science* **23**(11), 98–102 (in Chinese).
Zhang, Y and Yu, X (2007) Current research state and development of urban forestry. *Journal of South China University of Tropical Agriculture* **13**(1), 38–42 (in Chinese).
Zhao, X (2000) *The History of Beijing Gardens*. China Forestry Publishing House, Beijing (in Chinese).
Zhuang, G (2003) Air quality, urbanization, and automobilization in China. *Scientific Chinese* **2003**(8), 28–29 (in Chinese).