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Assessment of Ecosystem Services of Urban Green Space as a Tool for Sustainable Urban Development – The Case of Xi'an, China

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Contents

List of Figures

List of Tables

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Abstract

This study contributes to using ecosystem services as a concept for the design and planning of green spaces, taking the City of Xi'an, Central China, as a case study. The aims of the study were to (a) develop and apply an approach for the rapid appraisal of ecosystem services provided by urban green space; (b) identify the relationships between park features and their ecosystem services; (c) assess park visitors' use habits, perception and appreciation of ecosystem services; (d) draw conclusions for the future design and management of urban green space in Xi'an and Chinese cities.

The methodology consisted of a combination of methods from the natural and social sciences. Documentary analyses revealed the goals of green space plans and policies related to ecosystem services supply. Visual inspection of satellite imagery provided data of land cover which was complemented by a field survey to further analyse the types and compositions of land cover and vegetation structures of green spaces. Data on the use, recreational activities, perceptions, assessments and demands for green spaces by urban residents were collected by a questionnaire survey. Descriptive statistics were employed to show general patterns, whereas statistical tests such as t-test and one-way ANOVA were used to explore whether variations of socioeconomic backgrounds and park characteristics were related to green space use, perception, assessment and demands. Finally, based on the assessment indicators which were derived from the land cover, vegetation structure and the user questionnaire, an integrated approach was developed using simple rating rules to assess the ecosystem services generated by green spaces of Xi'an.

Document analyses show that the government of Xi'an has increasingly realized the importance of ecosystem services. Green spaces' plans and managements have also stressed the need to develop multifunctional green spaces in order to provide ecological and recreational green spaces.

The results of the field survey reveal that six types of land cover and eleven types of vegetation structure can be distinguished in the 22 urban parks of Xi'an city. Vegetation accounts for most of the area. Multi-layered trees covering shrubs and lawns and trees covering shrubs and lawns are the dominant types of vegetation structure. Older parks usually show more variations in compositions of land cover and vegetation structure. Larger parks located within the third ring road have a higher percentage cover of lawn and the older parks located within the second ring road of Xi'an have more playgrounds.

Most of the respondents in Xi'an frequently use the nearby urban parks for short stays (1-2 hours). Elderly people are the main user groups of green spaces. Respondents show preferences

for passive recreational activities when they visit green spaces, such as to enjoy the scenery, to have large greenery and to contact with nature. The elders enjoy a broader range of activities in green spaces compared with the other age groups. Also, respondents prefer to do activities in the larger and newer parks and in the parks with 26-50% of multi-layered vegetation and evergreen species.

Respondents have the view that shading, O_2 release, recreational places, contact with nature and aesthetics are the most important services provided by green spaces. They perceive these ecosystem services more important in the small to medium and medium sized parks (5-10 ha and 10-30 ha) with relatively higher percentage of multi-layered vegetation, tree and mature trees and medium percentage of evergreen species.

Overall, less than half of the respondents positively assessed green spaces of Xi'an. Comparatively, the more positive assessments are for vegetation coverage, microclimate, cleanliness and scenic beauty while the provision of water area, water quality and air quality were rated less favourably. Not surprisingly, for respondents which have children air quality and availability of playgrounds were important criteria for assessment of parks. Older parks, which are located within the second ring road and have a size of 10-30 ha and 0-5 ha, received relatively higher positive assessments.

Moreover, the respondents clearly expressed the need for more shade, opportunities to watch nature, flowers and better management of green spaces. However, demands differed between age groups and levels of education. Older respondents wanted more quiet places and play areas for children. Students wanted more sporting facilities and employed wanted more cafes and restaurants. In addition, respondents interviewed in the older parks located within the second ring road expressed wishes to increase provision of a larger number of ecosystem services such as more safe places. Their needs for the ecosystem services are also influenced by the different coverage of vegetation structures. For example, respondents in the parks with 26-50% of multi-layered vegetation and 0-25% of evergreens demanded more shade.

Generally, in Xi'an city, urban parks provided similar levels of regulation for microclimate and air quality and these regulation functions were predominantly considered to be high or medium high. The older parks with a small to medium size and located within the second ring road received higher assessments on regulation functions. However, all parks were considered to have a low value in recreational services regardless of park character.

All the findings contribute new knowledge on regulating ecosystem services, landscape preferences, leisure studies and citizen assessments and demands of ecosystem services for the planning, design and management of urban green spaces. Six general strategies using ecosystem services as approaches can be proposed to advance the quality of green spaces: to maintain sufficient green spaces in the limited available lands; to maintain the number of vegetation structure types and plant species; to balance the provisions of regulating and recreational services; to incorporate citizens’ considerations into the process of green space planning; and to develop a system for better management of green spaces.

Kurzfassung

Weltweit hat die Urbanisierung zu vielfältigen Problemen geführt wie etwa der Degradierung von Natur und Umweltverschmutzung in Städten, einem hohen Verbrauch von Energie und natürlichen Ressourcen wie auch hohen Treibhausgasemissionen.

Städtische Grünflächen können einige dieser Probleme durch die Bereitstellung von Ökosystemleistungen vermindern. Wie städtische Grünflächen zu planen und zu pflegen sind, um durch ihre Ökosystemleistungen die städtische Umwelt- und Lebensqualität zu erhöhen, und eine nachhaltige sowie klimaresiliente Stadtentwicklung zu fördern, ist daher zu einem wichtigen Forschungsgebiet geworden.

Diese Untersuchung soll dazu beitragen, den Ansatz der Ökosystemleistungen für die Gestaltung und Planung verstärkt zu verwenden, mit der Stadt Xi'an in Zentralchina als Fallstudie. Ziele der Untersuchung waren (a) einen Ansatz für die einfache und rasche Erfassung und Bewertung von Ökosystemleistungen städtischer Grünflächen zu entwickeln und zu erproben, (b) die Beziehungen zwischen der Beschaffenheit der Parkanlagen und den Ökosystemleistungen zu analysieren, (c) die Nutzung der Parks, sowie die Wahrnehmung und Wertschätzung der Ökosystemleistungen durch die Parkbesucher zu ermitteln, und (d) Schlussfolgerungen für die zukünftige Gestaltung und Pflege von städtischen Grünflächen in Xi'an und anderen chinesischen Städten zu ziehen.

Die Vorgehensweise bestand aus einer Kombination von natur- und sozialwissenschaftlichen Methoden. Eine Dokumentenanalyse zeigte, wie Ökosystemleistungen in der städtischen Grünflächenplanung gegenwärtig Berücksichtigung finden. Durch die visuelle Auswertung von Satellitenbildern wurden Landbedeckungsdaten erhoben, ergänzt um ein Felderhebung für die nähere Analyse von Landbedeckung und Vegetationsstrukturen in den Grünflächen. Daten zur Grünflächennutzung, zu den Erholungsaktivitäten, der Wahrnehmung von Grünflächen, ihrer Wertschätzung sowie der Nachfrage nach Grünflächen wurden durch fragebogengestützte Interviews durchgeführt. Diese Daten wurden einerseits mit deskriptiven Statistiken ausgewertet, während die Beziehungen zwischen Nutzungs- und Wahrnehmungsmustern und sozioökonomischen Merkmalen der Parkbesucher mit der Parknutzung, ihrer Wahrnehmung, Bewertung und Nachfrage nach Ökosystemleistungen durch t-Tests und einfache Varianzanalysen (ANOVA) überprüft wurden. Schließlich wurde aus den Daten zu den Landbedeckungsarten, der Vegetationsstruktur und den Interviewergebnissen ein integrierter Ansatz zur Bewertung der Ökosystemleistungen städtischer Grünflächen entwickelt und für Xi'an angewendet.

Die Auswertung der Planungsdokumente zeigt, dass die Regierung von Xi'an den Ökosystemleistungen der Grünflächen zunehmende Bedeutung beimisst. Die Grünflächenpläne enthalten auch Ziele zur Entwicklung von multifunktionalen Grünflächen, die sowohl ökologische als auch Erholungsfunktionen erfüllen sollen.

In den Feldbegehungen wurden in den 22 städtischen Parks von Xi'an sechs Landbedeckungsarten und elf Vegetationsstrukturtypen unterschieden. Die Vegetation nimmt die größten Flächenanteile an den Grünflächen ein. Mehrschichtige Gehölzstrukturen und Baum-Strauch-Rasen-Strukturen sind die vorherrschenden Vegetationsstrukturtypen. Ältere Parkanlagen zeigen eine größere Variation der Landbedeckungsarten und Vegetationsstrukturen. Größere Parkanlagen innerhalb der dritten Ringstraße haben einen höheren Anteil an Rasenflächen und ältere Parks innerhalb der zweiten Ringstraße von Xi'an zeichnen sich durch mehr Spielflächen aus.

Die Mehrzahl der befragten Parkbesucher Xi'ans besuchen regelmäßig die nahegelegenen Parks für einen kurzen Aufenthalt von 1-2 Stunden Dauer. Ältere Menschen sind die Hauptnutzergruppe. Die Befragten bevorzugen passive Erholungsformen wie etwa das Betrachten des Parks sowie Natur zu erleben. Die älteren Parkbesucher üben eine größere Anzahl von Aktivitäten in den Parks aus als die jüngeren Besucher. Die älteren Parkbesucher bevorzugen dabei größere und jüngere Parkanlagen, sowie Parks, in denen mehrschichtige und immgrüne Gehölze einen Flächenanteil zwischen 26-50% einnehmen.

Die Parkbesucher sind der Auffassung, dass die Verschattung, Sauerstofferzeugung, das Vorhandensein von Erholungsflächen, der Naturkontakt und die Ästhetik die wichtigsten Ökosystemleistungen sind. Sie halten die Bereitstellung von Ökosystemleistungen für besonders hoch in den kleineren und mittelgroßen Parkanlagen (5-10 ha und 10-30 ha) mit einer mehrschichtigen Vegetationsstruktur, großen Bäumen und einem mittleren Anteil von immergrünen Arten.

Insgesamt bewerteten weniger als die Hälfte der Parkbesucher den Zustand der Grünflächen von Xi'an positiv ein. Vergleichsweise besser bewertet wurden die Vegetationsbedeckung, die klimatischen Leistungen, die Sauberkeit und die Schönheit der Grünflächen während das Vorhandensein von Wasserflächen, die Wasserqualität und die Luftqualität weniger gut bewertet wurden. Für Befragte, die Kinder haben, waren erwartungsgemäß die Luftqualität und das Vorhandensein von Spielplätzen besonders wichtige Bewertungskriterien. Ältere Parkanlagen innerhalb der zweiten Ringstraße und mit einer Größe von 0-5 ha bzw. 10-30 ha wurden besser als die andern Grünflächen bewertet.

Die Befragten wünschten sich mehr Schatten, Gelegenheiten für die Naturbeobachtung, Blumen und eine bessere Grünflächenpflege. Die Bedürfnisse unterschieden sich aber zwischen den Altersgruppen und Bildungsniveaus. Ältere Parkbesucher wünschten sich mehr ruhige Plätze und Spielplätze für Kinder. Studenten waren dagegen an mehr Sporteinrichtungen interessiert und Angestellte wollten zusätzliche Cafés und Restaurants. Die Besucher der älteren Parks innerhalb der zweiten Ringstraße äußerten den Wunsch nach mehr Ökosystemleistungen und auch nach erhöhter Sicherheit. Ihre Nachfrage nach Ökosystemleistungen stand in Beziehung zur Vegetationsstruktur. So wünschten sich beispielsweise Besucher von Parkanlagen mit einem Anteil mehrschichtiger Vegetation von 26-50% sowie einem Anteil von 0-25% an immergrünen Gehölzen mehr Schatten.

Insgesamt stellten die Parks in Xi'an in vergleichbarem Umfang klimaregulierende und die Luftqualität verbessernde Ökosystemleistungen bereit und diese Leistungen wurden als überwiegend hoch oder mittelhoch eingeschätzt. Die älteren, kleinen bis mittelgroßen Parkanlagen innerhalb der zweiten Ringstraße wurden dabei besser bewertet. Auf der anderen Seite erhielten alle Parkanlagen eine niedrige Bewertung in Bezug auf ihre Erholungsqualität.

Diese Ergebnisse haben eine hohe Bedeutung für die Planung, Gestaltung und die Pflege der Grünflächen, um ihre Ökosystemleistungen zu stärken. Sechs Strategien werden dazu vorgeschlagen: Sicherung der Grünflächen in dicht bebauten Stadtgebieten; Sicherung vielfältiger Vegetationsstrukturen und der Biodiversität in den Parks, Berücksichtigung und sorgfältige Abwägung von Maßnahmen zur Bereitstellung von regulierenden und Erholungs-Funktionen, und die Verbesserung der Grünflächenpflege.

1 Introduction

1.1 Urbanization and Urban Challenges

Urbanization is a global phenomenon. In today's world, the urban population accounts for 54% of the total global population (WHO, 2015). By the year of 2050, it is expected that more than 66% of the world population of more than six billion people will live in cities (UN 2014). Nowadays urbanization in Asia is proceeding at a rate much higher than the world average (Ooi 2009). Particularly, the growth of megacities with a population of over 10 million is characteristic of urbanization in Asia (Ooi 2009). China as the biggest country of Asia has experienced a particularly fast urbanization, industrialization, and a dramatic population explosion in cities (Shuqing Zhao 2006). The percentage share of the urban population in China more than doubled from 19% in 1980 to approximately 47% in 2010 and is excepted to reached 59% in 2025 (UN 2010). In 1980, there were only 51 cities with half a million inhabitants in China. Between 1980 and 1995, another 51 were added to the group and, between 1995 and 2010, 134 additional cities in China crossed the half a million threshold. By 2025, it is expected that there will be another 107 cities with more than half a million inhabitants in China (UN 2010).

Urbanization is considered as a basis for rapid social development and economic growth, but at the same time it can have great negative impacts on the quality of human life and the environment (NRC 2001), such as global warming and waste generation (Georgi and Dimitriou 2010; Grimm NB 2008; M. Feliciano 2008). In addition to these negative impacts both on regional and global scales, urbanization also leads to environmental problems within urban areas, for instance, poor housing conditions in crowded cities, traffic congestion, a shortage in natural resources such as clean drinking water (Li et al. 2005; Min et al. 2011). Furthermore, urbanization causes the destruction, fragmentation and the disturbance of natural ecosystems (Blair 1999; McKinney 2002). The replacement of vegetation areas by artificial land cover, such as buildings and roads leads to increased mean temperatures compared with surrounding rural areas and the various human activities in urban areas lead to higher concentrations of green-house gases and atmospheric pollutants (Grimm NB 2008; WHO 2002). Moreover, the impervious surfaces decrease infiltration of rainwater, as a result, surface runoff is greatly increased, which may lead to the heightened risk of flooding (Pauleit 2000; Tyrväinen 2005). The deteriorating environment also results in physical and mental health problems for urban dwellers (Shuqing Zhao 2006).

Now these urban problems are severe in most Asian countries where economic development has been prioritized over environmental concerns. The most obvious example is the air in Asia's cities which is among the most polluted in the world (Ooi 2009). China has already exposed to nearly all these problems of the environment since the 30 years' rapid urbanization. In extreme cases, the growing urban areas are becoming increasingly vulnerable to natural disasters, such as, the frequent dust storms in the northern areas of China, e.g. Beijing and Shijiazhuang (Qian et al. 2002; Shuqing Zhao 2006).

1.2 Importance of Urban Green Spaces

Since the awareness of environmental degradation, a national strategy for sustainable development - China's Agenda 21 (Department of Planning Committee of China 1994) - has been established, aiming to reduce the negative environmental impacts of economic development while at the same time aiming to maintain economic and social benefits, and finally attain a durable provision for human needs (Kyrkou and Karthaus 2011). This strategy emphasizes land use management and the development of greener cities (Shuqing Zhao 2006).

In response, the concept of the "ecological city" was proposed by city planners to meet these challenges. The eco-city is a broad concept which encompasses economic, social and environmental objectives (Yijun 2011). Within this concept, urban green space has been raised as a topic of particular importance in recent years. Amount of public green spaces, public parks and recreation areas are often mentioned as important factors to make cities more livable, pleasant and attractive for citizens (Kyrkou and Karthaus 2011).

In reality, the role of urban green spaces has been recognized at least since the 19th century when it was considered as a response to the problems created by industrialization in Europe and elsewhere (Nicol and Blake 2000). Since then, urban green space is thought to be helpful of better city development (Hansen et al. 2015; Jim and Chen 2008a). At present, green spaces planning increasingly adopts the concept of urban green infrastructure, i.e. a coherent and multifunctional network of green spaces that can, for instance, encompass public parks, woodlands and farmlands near urban areas as well as private green spaces (e.g. gardens) to address the challenges of urbanization. The multiple values of green spaces are conceptualized as ecosystem services (Bolund and Hunhammar 1999; Hansen et al. 2015; Tratalos et al. 2007; Tyrväinen 2001). In order to achieve the basic goal of sustainable development the following ecosystem services are essential, for instance, moderating the urban heat island effect (Leo et al. 2016; Yuan 2007), removing pollutants from air and water (Cohen et al. 2014), providing recreational opportunities and aesthetic enjoyment thereby raising the quality of urban life (Rall et al. 2017; Tzoulas et al. 2007), protecting soil quality, abating noise and reducing energy consumption (Cohen et al. 2014; Yeh 2009). Furthermore, green spaces can provide a basis for biodiversity, such as provide habitats for plants and animals (Hiroaki T. Ishii 2010), also can characterize and enhance the image of the cities, such as Central Park in New York, Royal Parks in London, and Red Square in Moscow (Nasar 1997). Well-designed urban green spaces can achieve many functions simultaneously, for instance, a reduction in energy consumption by shading the buildings and a contribution to abating noise and air pollution around the buildings (Bolund and Hunhammar 1999). A network of high quality green spaces can also attract business, retail and leisure facilities and thus strengthen the local economy (Cianga and Popescu 2013).

China has a long history of garden planning, tree planting along roads and water edges (Yu et al. 2006). The core of traditional Chinese gardening is to imitate the beauty of nature (Lou 2003). Therefore aesthetic qualities are rather emphasized than ecological values. This tradition influences the greening policy and style of contemporary Chinese landscape architecture and leads to researches about urban green spaces mostly focus on the design and planning of recreational green spaces. However, there is still a severe lack of the recognition of ecosystem services generated by urban green spaces and their benefits to the health of urban ecosystems. Whilst an understanding of the multiple functions of urban green spaces, such as the above-mentioned ecological and cultural ecosystem services' provisions is reasonably well-developed in science, it also needs to be well integrated into the planning, design and management processes (Yli-Pelkonen V 2005). However, reliable and robust approaches to effectively support this integration are often absent (Tyrväinen 2001). Therefore, it is necessary to develop approaches that comprehend the ecosystem services supply and demand of green spaces, and enhance the integration of the ecosystem services concept into green space planning and management.

Xi'an as a very important inland city in China is very worthy of such research. In recent decades, the city has experienced a high speed urbanization with tremendous land use changes and hence a formed compact city fabric (Lu and Peng 2006). There are 11,166 persons per km^2 in central city area (XUPB 2010). The high urban density reduces the accessibility of unsealed surface for residents. Urban green lands are particularly limited compared with other land uses. The government of Xi'an city has realized the severity of these problems and undertaken a series of studies and policies, for instance, the 1995-2010 Master Plan of Xi'an for urban environmental protection, in particular for air quality and water quality (XAEPB 2000) and the "Urban Green System Plan (1995-2010)" for keeping ecological functions started in 1995. Since then, the green cover ratio had risen to approximately 32% in 2010, which is slightly higher than the "national garden city" norm of 30% (Xi'an Statistic Yearbook 2011). While comparing the green coverage with the other national garden cities, such as 45% in Beijing and 38% in Shanghai, it is relatively low, not to mention such cities with higher greening quality such as Paris, Stockholm (see the website http://www.stats-sh.gov.cn/tjnj/nj11.htm?d1=2011tjnj/C1016.htm and http://www. bjstats.gov.cn/bjsq/csjs/). The contributions of green spaces thus need more attention and conservation. The deterioration of natural urban ecosystems and the request for high quality of urban life provide a challenge for the city to maintain and increase the natural values and functions of existing green spaces, as well as to introduce more green spaces into urban areas. In practice, in Xi'an city, little is known about whether green space quality and the provision of ecosystem services have actually improved, and whether the ecosystem services provided by urban green spaces meets the citizens demands. Such unknowns provide development potentials and give us an opportunity for choosing Xi'an as our case study, where the urban green spaces urgently need to be improved by comprehensive planning, policies and management relying on ecosystem services.

1.3 Aim and Objectives of the Research

Since the increasing realization of the importance of green spaces and their ecosystem services to alleviate the problem of urbanization and hence to benefit sustainable urban development, the overall aim of this study is to contribute to using the concept of ecosystem services for design and planning of green spaces in Chinese cities. The objectives of the study are :

Objective 1: Develop and apply approach for the assessment of ecosystem services provided by urban green space;

Objective 2: Identify the relationship between park features and ecosystem services;

Objective 3: Assess urban park use, perception and appreciation of ecosystem services by park users;

Objective 4: Explore how green space planning and management can better contribute to enhancing ecosystem services in Chinese cities.

1.4 Organization of the Research

The research will be presented in four stages (see figure 1.1) and assigned to seven chapters.

This chapter has outlined some of the issues underpinning current urban green spaces debates and described the research objectives. Chapter 2 reviews the relevant concepts, typologies and research development regarding urban green spaces and their ecosystem services, also introduces the evaluation methods of ecosystem services mainly regarding non-monetary assessments and questionnaires. It also summarizes a series of ecosystem services indicators generated by urban green spaces using land cover mapping method for the assessment in the next stage. Chapter 3 describes the case study – Xi'an City including the geographical location and the socio-economic and environmental conditions, the research area and the urbanization process. It also introduces the research methods used in this study, including a simple non-monetary assessment, land cover mapping, questionnaires and document analysis. The simple assessment method embraces an indicators system, assessing rules and aggregation rules. In addition, the procedures of data collection during field survey were described in a few paragraphs. Chapter 4 shows the urban green spaces plans and development of Xi'an city from the establishment of first plan. Chapter 5 shows the types of land cover and vegetation structure of green spaces in Xi'an city and discusses the research findings with other studies. Chapter 6 reveals respondents' use habits, perceptions, assessments and demands for the green spaces in urban parks of Xi'an city. It also tries to explain the reasons of respondents' choices and compares the questionnaire findings with other studies. Chapter 7 shows the assessment results of regulating services using simple non-monetary assessments and the assessments results of recreational services using questionnaires. It tries to explain the possible reasons for these findings as well. Finally, chapter 8 will draw the final discussion and conclusions and make suggestions for improvements of green spaces in Xi'an and in other Chinese cities.

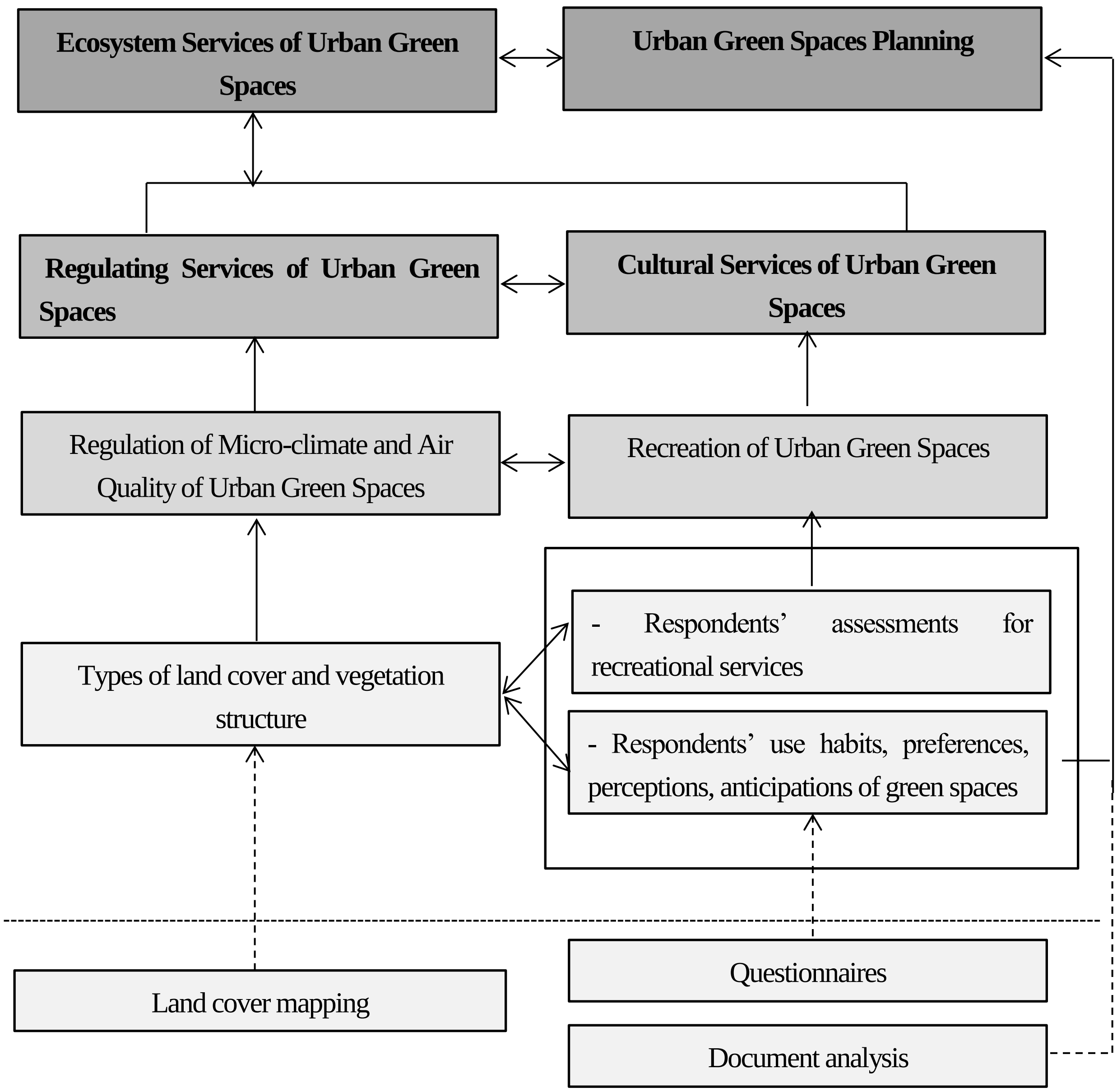

Figure 1.1 Research flow chart

2 Literature Review

2.1 Urban Green Spaces and Ecosystem Services

2.1.1 Concept and Classification of Urban Green Spaces

Definitions of green spaces are manifold and depend on the purpose of the study in question (Swanwick et al. 2003). In some cases, the term urban green space refers to those public and private open spaces in urban areas, which are predominantly covered by vegetation, either natural or artificial, and are directly or indirectly available to the public (Baycan-Levent et al. 2009; Haq 2011; Jim 2003). By this definition, green spaces may include water features, buildings and impervious surfaces such as paved trails and amenities, in addition to grasses, trees, shrubs and other vegetation (Dunnett 2002; Forsyth 2003; Jim 2003; Lo and Jim 2011).

Due to the breadth of the definition, a vast variety of urban places can be described as urban green spaces. Considering their characteristics, such as naturalness, type, size and location within the cities, as well as their multiple functions ranging from nature conservation to recreation, a distinction of urban green spaces from other green space types can be made. For example, from an urban ecology perspective, urban green spaces can be broadly grouped into four types of urban nature: remnants of pristine landscapes such as natural woodlands; remnants of cultural landscapes such as intensively managed forests and agricultural lands; designed landscapes such as artificial gardens and parks, and other urban greenery, e.g. street trees; and urban wilderness, i.e. areas of former urban use recolonized by vegetation (Kowarik 2005). By contrast, a multipurpose classification has been suggested by Swanwick et al. (2003). A distinction is made between functions of green spaces (e.g. recreation), economic value and habitats. Therefore, urban green spaces include parks, gardens, farmland, school grounds, wetlands, woodlands, et cetera. Similarly, in Australia, Ambrey and Fleming (2014) considered the multi-functionality and naturalness, and hence defined green spaces with examples including public parks, community gardens, cemeteries, sports fields, national parks and wilderness areas. In the context of China, according to the "Standards for the Classification of Urban Green Spaces", urban green spaces are divided into nine categories: public park, square, nursery, green buffer, attached green space, residential green space, roadside/street green space, riparian green space, and scenic forest (see Table 2.1) (CMC 2007). This classification considers both multiple human functions and naturalness.

Table 2.1 Classification of urban green spaces in China (source: CMC, 2007)

Original urban green space type	Reclassified patch type	Abbreviation	Description
Public park	Public park	PU	Open to the public (includes community parks); provides education, pleasure and recreation; has natural and planted vegetation
	Plaza-green space	PL	Open to the public; provides open space, recreational opportunities; has planted vegetation, seldom trees, most is shorter shrubs and grassland; low diversity
Nursery		NU	Propagating and cultivating vegetation, breeding and supplying saplings for urban greening
Green buffer		GR	Linear corridors protecting high-voltage transmission lines, shielding wind and filtering pollutants; with planted vegetation
Attached green space	Attached green space	AT	Attached to industrial, commercial, utility land, etc.; contains planted vegetation; low diversity
	Residential green space	RE	Attached to residential areas, including those planted and maintained by the individual residents; includes communal green space serviced by the local community (excludes PU and PL). Provides aesthetic, amenity-recreation venues; limited plant diversity
	Roadside green space	RO	Linear corridors between sidewalks, curbs or island patches in crossroads; serves to buffer people from traffic, reduces noise, solar radiation, etc.; contains planted vegetation; limited plant diversity
Other green space	Riparian green space	RI	Linear corridors along watersheds; primarily natural habitat type; often high plant diversity
	Scenic forest	SC	Open to the public; serves to protect and preserve flora, fauna and provides scenic amenities; a mosaic of remnant- or naturalized habitat types

No matter which classification is used for urban green spaces, urban parks are always included as a type of green space. According to the terms stipulated in "basic term standards" of Chinese landscape architecture (CMC 2007), urban parks are defined as green spaces available for the public to visit, appreciate, rest in, participate in activities and do sports. Lin included fire protection, disaster prevention and refuge as further functions of such parks (Lin 1995). Therefore, urban parks are used not only for public recreation (CMC 2007) but also for assembly in case of fire, earthquake, and other emergencies (Lin 1995).

Parks have been classified in different ways, but size, facilities, functions and accessibility are often the main criteria. For example, the US classification paid more attention to the distinctions between park functions, such as playing areas, sports fields, zoos and memorial parks (Bonsignore 2003). In the city of Los Angeles, the park definitions include recreation center, pocket/mini park, open space, dog park and playground (Luo and Li 2015). In China, researchers have attempted to divide the urban parks into historical sites, recreational parks, comprehensive parks, community parks and ecological parks (Jin and Hong 2015). An official classification - the "Classification of Chinese Cities" - has been published by the Construction Ministry of P.R. China in 2007. Urban parks were classified into four categories and 31 sub-types according to the classification (CMC 2007) (see Table 2.2). This classification focuses not only on area and service radius, but also on the function and shape of urban parks. A park's area and service radius are the basic data for assessing the provision of ecosystem services to the surroundings.

2.1.2 Concept and Classification of Ecosystem Services in Urban Green Spaces

Ecosystem services are defined as the benefits humans derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997; De Groot et al. 2002; MA 2003). It is also used to refer to the aspects of ecosystems utilized, actively or passively, to produce human well-being (Davidson 2013; Fisher et al. 2009; TEEB 2010). Bolund and Hunhammar (1999) introduced the term "urban ecosystem services" for the first time. The authors outlined the value and benefits that urban residents can obtain from internal ecosystems located within a city.

Compared to undisturbed natural ecosystems, urban ecosystems have been influenced by humans to varying degrees during the process of urbanization (McIntyre et al. 2000). Considering entire urban areas as urban ecosystems, urban ecosystems are described as complex, dynamic bio-physic-social entities, in which people live at high densities, or where the built infrastructure covers a large proportion of the land surface (Maes et al. 2016; Pickett et al. 2008; Pickett et al. 2001). Human activities modify the natural components of urban ecosystems by changing the vegetation cover, removing plants and top soil, introducing exotic species, as well as polluting the air, water and soil (Redman 1999).

Table 2.2 Classification of urban parks in China (source: CMC, 2007)

Park type	Subdivision		Area (ha)	Service radius (km)
Suburban scenery park	Suburban national scenery park			
	Suburban provincial scenery park			
	Suburban municipal scenery park			
Country park	Country comprehensive park		50	5-10
	Country wetland park			
	Country forestry park			
	Farm recreation park			
	Cemetery			
	Other country park			
Municipal park	Comprehensive park	Municipal comprehensive park	10-50	3-5
		District comprehensive park	10	1-3
	Belt park	Manmade belt park		
		Natural belt park		
	Local park	Square		
		Residential park	5-10	0.5-1
		Roadside park	0.001	0.3-0.5
		Neighborhood park	0.001	0.3-0.5
		Other local park		
Specialized park	Educational park	Zoo		
		Botanical garden		
		Defense park		
		Other educational park		
	Theme park	Sculpture park		
		Musical park		
		Amusement park		
		Other theme park		
	Children's park			
	Sports park			
	Historical park			
	Memorial park			
	Other specialized park			

Accordingly, the land use types in urban areas are changed. Natural areas have been transforming into built-up areas including buildings, rooftops, sidewalks, roads and parking lots (Arnold and Gibbons 1996). Ecological consequences of the altered urban land uses have resulted in environmental problems, such as air pollution, heat island effect, habitat destruction and degraded water quality, with impacts on human well-being and quality of urban life (Bolund and Hunhammar 1999; Gardiner et al. 2013; McKinney 2002). Urban ecosystem services can locally mitigate these problems, since they are primarily, but not exclusively, related to the environmental functions provided by urban green spaces (De Groot et al. 2002; Gardiner et al. 2013; Niemelä et al. 2010; Tratalos et al. 2007; Whitford et al. 1998).

Niemelä et al. (2010) discussed the ecosystem services of urban green spaces and adapted a classification of these ecosystem services into three categories: provisioning services, regulating services and cultural services (see Table 2.3). Provisioning services are material benefits that ecosystem services generate, such as food, fresh water and timber. Regulating services, such as the regulation of microclimate and air quality, gas cycles and water infiltration, are essential preconditions for other ecosystem services. Cultural services are immaterial benefits that humans derive from ecosystems, e.g. through recreation, health benefits and education (MA 2005). Similar to the TEEB (2010) and CICES (2016) classifications, this classification also does not include the MA (2005) category "supporting services", and habitat provision was merged into the category of "regulating services".

2.1.3 Contributions of Urban Green Spaces to the Provision of Ecosystem Services

There is an increasing amount of research on the contributions of urban green spaces to temperature regulation, air purification, biodiversity conservation, carbon sequestration and noise reduction, as well as human health and recreation (e.g. Cao et al., 2010; Zhang et al., 2014; Yin et al., 2011 and McPhearson et al., 2013). For instance, green spaces, and especially large areas of city parks, can become islands which are cooler and more humid than the surrounding urban environment on hot summer days (Barradas 1991; Martina Petralli 2009). The possible maximum air temperature reduction attributed to green spaces was found to be 1-2 °C, and sometimes even 5-7 °C (Katayama et al. 1993; Kikegawa Y 2006; Rosenfeld et al. 1998). Parks with a wide variety of vegetation also play a particularly important role in amending the air quality in urban areas. For example, in Shanghai, China, Yin et al. (2010) found that parks remove 2-35% of total suspended particulate (TSP), 2-27% of SO_2, and 1-21% of NO_2 in different seasons (Yin et al. 2011).

Table 2.3 Ecosystem services generated by green and water areas in urban regions (source: Niemelä et al., 2010)

Group	Service	Service-generating unit
Provisioning services	Timber	Different tree species
	Food	Different species in land-, freshwater- and marine ecosystems
	Fresh water, soil	Groundwater infiltration, suspension and storage
Regulating services	Microclimate regulation	Vegetation, water
	Gas cycles (O_2 production, CO_2 consumption)	Vegetation, especially forests
	Carbon sequestration and storage	Vegetation, especially trees
	Habitat provision	Biodiversity
	Reduction of air pollution	Vegetation, soil microorganisms
	Noise reduction	Protective green areas, thick/wide forests, soft surfaces
	Rainwater absorption	Vegetation, unsealed surfaces, soil, water
	Water infiltration	Wetlands, vegetation, microorganisms, water
	Pollination	Insects, birds, mammals
	Production of topsoil and maintenance of its nutrient content	Litter, invertebrates, microorganisms
Cultural services	Recreation	Biodiversity, especially in parks, forests and water ecosystems
	Psycho-physical and social health benefits	Forests
	Science education, research and teaching	Biodiversity

Urban green spaces provide recreational opportunities and amenities, which are key factors of life satisfaction and psychological well-being (Jim and Chen 2006a; Leitner and Leitner 1996). Parks provide a peaceful and relaxing setting for stressed urban inhabitants. They are "second living-rooms" for people living in confined quarters. Moreover, they offer sports fields and activity spaces for an increasingly overweight city population. Green spaces are also environments for children to play and to discover the world; they are active and social places for youth (Aarts et al. 2012; Granzin and Williams 2012; Woolley 2006).

Moreover, urban green spaces provide valuable habitats for animals and plants, and some species respond strongly to environmental changes and dispersal corridors (Bolger et al. 2001).

Therefore, urban green spaces possess a considerable potential to contribute to the biodiversity of cities (Kühn 2004; Millard 2010). For example, birds are attracted by the rich supply of foods and the wide array of potential nesting sites in green spaces, and this sometimes includes even rare and endangered species (Volker Heidt 2008). Parks often have higher biodiversity than other types of urban green space such as woodlands, gardens and green roofs, with more woody plant species, due to their often high levels of habitat diversity and microhabitat heterogeneity (Jim and Chen 2008b, 2009). Therefore, parks can constitute particularly important hotspots of biodiversity in the cityscape (Cornelis and Hermy 2004).

2.1.4 Relationship between Ecosystem Services and Features of Urban Green Spaces

All the natural components of urban ecosystems, such as vegetation, forests, water, soil, animals and biodiversity, can be generators of ecosystem services (see Table 2.3). Nevertheless, biodiversity, water, and especially vegetation, can be considered the most important generators of ecosystem services in urban green spaces.

Biodiversity

Biodiversity is related to the generation of urban ecosystem services (Cardinale et al. 2012; Costanza et al. 2007; Haines-Young and Potschin 2010) (see Table 2.3). Relevant studies have demonstrated that urban biodiversity contributes to multiple ecosystem services which are very important for human well-being (Schneiders et al., 2012 and Thompson et al., 2014). Diversity of plant species brings about more diverse animal communities, since different animals rely on different plants. Furthermore, biodiversity is positively influenced by diversity of land uses. Additionally, higher biodiversity offers greater opportunities for interactions of people with nature (Miller 2002; Young 2010), helps foster an active lifestyle, and therefore benefits human health (Chiesura 2004).

Water

Water surfaces have also been demonstrated as generators of ecosystem services in urban areas. For example, water bodies provide recreational opportunities, such as boating, fishing, and swimming (Qiu 2009). Water surfaces affect not only the surface temperature, but also the air temperature, since water evaporates into the air absorbing excess heat in the process (Givoni 2000; Robitu et al. 2006; Sun and Chen 2012). Additionally, water possesses considerable storage capacity for the heat from solar radiation (Spronken-Smith et al. 2000). A study from the Petaling district, Malaysia, found that the lowest land-surface temperatures during the daytime appeared in areas with high-density forests and large water bodies (Buyadi et al. 2014a). Moreover, water regulates the temperature at the micro- and local- scale, such as within gardens and city parks (e.g. Givoni et al., 2000; Robitu et al., 2006; Huang et al., 2008 and Sun et al., 2012). In Beijing, 197 water bodies were found to reduce the air temperature by amounts ranging from 0.03 to 2.2 °C/hm, with an average of 0.54 °C/hm (Sun and Chen 2012). The thermal capacity of water is more obvious in the less-humid and arid locations (Kassem 1994). For example, in the arid area of Tabriz, Iran, the surface temperature of water was 5-9 °C cooler than on land, including areas covered with vegetation (Amiri et al. 2009).

Vegetation

Vegetation, and especially trees, plays the most important role in generating ecosystem services in urban areas, such as microclimate regulation, reduction of air pollution, and recreation (Bolund and Hunhammar 1999; Niemelä et al. 2010).

Vegetation can moderate the excess heat that accumulates in urban areas through evaporative cooling, shading, wind speed control and thermal capacity (Akbari et al. 2001; Andrade and Vieira 2007; Volker Heidt 2008). Evapotranspiration by plants consumes energy from solar radiation so that leaves and the surrounding air are less warmed up (C.S.B. Grimmond and T.R.Oke 1991; Taha HG 1988). Trees absorb and reflect the biggest part of solar radiation, and thus prevent the warming of the land surface underneath (Akbari et al. 2001; Katayama et al. 1993; McPherson 1994; Picot 2004). Vegetation affects air movements and heat exchange by increasing surface roughness and by providing corridors for ventilation in built areas (Bonan 1997). The phenomenon that air temperatures in winter are affected by wind speed reduction has been described by e.g. Akbari et al. (2001) and Volker Heidt (2008). However, this effect critically depends on the type of vegetation. At night, tree cover may retain warm air under the canopy, while open grassland may promote cooling of the air by convection (Armson et al. 2012; Potchter et al. 2006).

Urban vegetation, and especially trees, can directly or indirectly improve the local air quality (Nowak 2002). Vegetation reduces the amount of air pollution in cities by trapping, absorbing and degrading pollutants (Beckett et al. 1998; Paoletti et al. 2011). Dry deposition, including stomatal uptake and non-stomatal deposition on the plant surface, is a major mechanism by which plants absorb pollutants from the air (Fowler et al. 1989; McPherson 1998). Gaseous pollutants such as NO_2, O_3 and SO_2 may be directly absorbed through leaf stomata (C.L 2002). Water-soluble pollutants can be dissolved in the water layer on the moist leaf surface (McPherson 1994). After the absorption, gases will diffuse into the intercellular space and may be absorbed by water films or react with inner leaf surfaces (Smith 1990).

Particulate pollutants can be captured on the leaf surface, which results in either trapping them there or dispersing them into the soil during rain (C.L 2002; Givoni 1991b). However, the intercepted particles are often re-suspended into the atmosphere, washed off by rain or dropped to the ground with leaf and twig fall (Nowak et al. 2006). Consequently, vegetation is only a temporary retention site for many atmospheric particles.

Furthermore, it should also be noted that vegetation can negatively affect air quality through the emission of volatile organic compounds (VOC), thus promoting the formation of smog and O_3, particularly at ground level (Chameides et al. 1988). Consequently, it has been suggested to use low-VOC-emitting tree species (Haider 1996; Nowak 2000). Moreover, the production of pollen in spring by trees contributes to particulate pollution and impacts those who are allergic to pollen (Beckett et al. 1998). Despite these potential negative effects, increasing vegetation is considered a helpful way to reduce air pollution.

Vegetated areas are also important for recreation in cities. Vegetation generates different colors, textures, sounds and feelings depending on the season, time of day and weather conditions (Miller 1988), and it can be used as a screen and buffer, which plays an important role in blocking objectionable views and offering beautiful views to the residents (Millard 2010; Miller 1988). Furthermore, for many people, planting, cultivating and managing vegetation is in itself a form of recreation. Also, the fruits, nuts, leaves, wood and wood chips harvested from trees and other urban vegetation add to the recreational activities processes. In many cases, green spaces are supplemented with playgrounds and sports fields so that they make up a comprehensive recreational system. At the city scale, green spaces can be created both as landscape scenery and for recreation by using a multitude of available engineering and landscape skills (Millard 2000).

2.2 Assessment and Evaluation of Ecosystem Services Provided by Urban Green Spaces

2.2.1 Monetary and Non-monetary Evaluation of Ecosystem Services Provided by Urban Green Spaces

Given the importance of ecosystem services generated by urban green spaces, their different values should be taken into account so that suitable decisions on the planning and management of urban green spaces can be made. The various values with regard to ecosystem services generated by urban green spaces have been highlighted both theoretically and empirically. Among the reviewed literature, Baycan-Levent and Nijkamp (2004 and 2005) valued the ecosystem services of urban green spaces by different approaches, including ecological, economic, social, planning and multi-dimensional valuation (see Table 2.4). This classification emphasizes the complex and multi-dimensional structure of urban green spaces, and reflects a comprehensive evaluation from several perspectives at a conceptual level.

Table 2.4 Valuation methods used for ecosystem services generated by urban green spaces (source: Baycan-Levent and Nijkamp, 2004 and 2005a)

Values of urban green spaces	Functions and contributions	Valuation methods	
Ecological values	e.g. biological diversity, genetic diversity, climate regulation, absorption of air pollution	Monetary valuation	Avoided costs, cost-benefit analysis, willingness to pay
		Non-monetary valuation	Species and ecosystem richness indices, biodiversity index, keystone processes, health index, ecosystem resilience and stability analysis, hierarchical structure, population viability analysis, eco-regions or eco-zones
Economic values	e.g. provision of food, wood, fruits, and energy	Monetary valuation	Travel cost, hedonic pricing, avoided costs, replacements cost, stated preference methods
Social and cultural values	e.g. sports, sightseeing, culture, aesthetics, social interaction	Monetary valuation	Travel cost, tourism revenues, willingness to pay
		Non-monetary valuation	Questionnaires, contingent valuation
Planning values	e.g. city image, energy reduction, tourism, shelter	Monetary valuation	Cost-benefit analysis, willingness to pay, hedonic pricing
		Non-monetary valuation	Geographical information system method, multi-criteria decision method
Multi-dimensional values	e.g. scientific research, education, policy	Monetary valuation	Financial analysis, cost-benefit analysis, cost-effectiveness analysis, tourism revenues, taxes revenues
		Non-monetary valuation	Performance analysis, multi-criteria decision method, meta-analysis, value transfer, rough-set analysis, fuzzy-set analysis, content analysis

At a more general level, valuation methods of ecosystem services provided by urban green spaces can be divided into monetary and non-monetary ones (see Table 2.4). Monetary valuations usually include the stated preference method, hedonic pricing, contingent valuation, avoided costs, and willingness to pay. Methods used to determine economic values have the common characteristic of using monetary units as an indicator, which can be derived by different methods. For instance, the provisioning ecosystem services, consisting of directly marketable goods, such as drinking-water, food and raw materials are valued through market observation of reference prices (Tong et al. 2007). By contrast, studies of regulating services traditionally use stated preference methods to derive the values based on secondary markets. Among the monetary methods, hedonic pricing, stated preference methods and contingent valuation, were most frequently used (Costanza et al. 2006; Tyrväinen 2005) to evaluate services such as recreational (Tyrväinen and Miettinen 2000) and aesthetic benefits (Sander et al. 2010), as well as air quality (Bayer et al. 2009).

Although there has been a thrust to apply monetary methods to value ecosystem services, these methods are inappropriate for the totality and plurality of values which are characteristic of non-monetary indicators (TEEB 2010). Moreover, monetary values are generally highly context-dependent with regard to the socio-ecology, politics, and economics at any given time. Most economic, social and ecological values attached to urban green spaces are non-priced environmental benefits, which include pleasant scenery or peace and quiet - i.e. potential recreational opportunities (De Groot et al. 2002). Since such benefits are difficult to integrate into the monetary assessment procedure, it is not always necessary to express the values of ecosystem services in monetary terms.

Non-monetary valuations can be achieved using a large number of methods, such as contingent valuation, questionnaires, geographical information system (GIS) methods, multi-criteria decision methods, and performance analysis. The non-monetary assessments focus on regulating and supporting services. Among regulating services, air purification (e.g. Jim and Chen 2009 and Escobedo et al. 2011), the cooling effect of trees and parks (e.g. Shashua-Bar and Hoffman 2000), as well as carbon storage and sequestration (e.g. Lal 2004), are of primary interest.

Social, planning, and multi-dimensional values are most directly associated with cultural ecosystem services, such as psycho-physical health, place value, sense of community and identity, recreational and educational opportunities (Chiesura 2004). These values reflect emotional, affective and symbolic views attached to natural ecosystems in urban settings, which in most cases cannot be adequately expressed in terms of commodities or monetary units. Therefore, methods for assessing the value of cultural ecosystem services are usually aiming to establish their importance to human well-being (e.g. Ambrey and Fleming 2011 and Calvet-Mir et al. 2012). For example, using the data from questionnaire surveys, multivariate exploratory techniques, analysis of variance (ANOVA) and chi-squared test are the most common methods adopted to assess the cultural ecosystem services. Some studies used both questionnaires and interviews to document citizens' preferences for recreation (Kaplowitz, 2001 and Qiu et al., 2015). While these methods do not provide monetary valuations of recreation, they can provide useful information on the importance of recreation to people in ways that monetary assessments cannot. Also, some studies used a combined assessment of social and ecological values to compare the provision of ecosystem services with the perception of well-being (Fuller et al. 2007). In recent years, an increasing number of studies have concentrated on applying more integrated evaluation methods. For example, questionnaires integrating collaborative geographic information system (GIS) techniques were used to determine people's attitudes towards urban green spaces (Balram and Dragicevic 2005).

However, most of the studies included in a review on urban ecosystem services (Haase et al. 2014) were conducted in developed countries, and nearly 60% of the studies focused on a single service, while multiple service valuations are still rare. Many studies presented the urban ecosystem services at a regional or city scale, whereas only a few were conducted at a neighborhood or local-site scale. For the whole city, the values of ecosystem services are rarely addressed at the operational level, and little work has been done on how the ecosystem services approach may be used to better incorporate non-monetary values in urban planning (Gómez-Baggethun and Barton 2013).

2.2.2 Indicators for the Evaluation of Ecosystem Services Provided by Urban Green Spaces

Ecosystem service indicators are used to evaluate the supply of, demand for, and trends of provision of ecosystem services, making the conditions, trends and rates of change of ecosystem services easily understandable (Layke 2009; Sparks et al. 2011). Indicators should be easily understood by policy makers and other non-scientific audiences so that the importance of the ecosystem services generated by urban green spaces for the economy, environment and human well-being will be well-appreciated. With the help of such indicators, ecosystem services of urban green spaces can be represented and evaluated easily, and policy-makers can make decisions based on evidence.

A broad range of indicators have been used to assess the ecosystem services provided by urban green spaces (Sparks et al. 2011). Different indicators have been used to assess provisioning, regulating and cultural services, such as those pertaining to recreation, biodiversity, ecology, climatology and forestry (Sparks et al. 2011). For example, the recreation services can be measured using indicators such as size and structure of green spaces (e.g. Ulf G. Sandström, 2009 and Onder et al., 2011), the number of visits and the frequcy of use (e.g. Carlos Smaniotto Costa et al., 2004), distance and accessibility of green spaces (e.g. Onder et al., 2011 and Gupta et al., 2012), willingness to pay (e.g. Lorenzo et al., 2000 and Casado-Arzuaga et al., 2013), the motivation of users (e.g. Carlos Smaniotto Costa et al., 2004 and Lo and Jim, 2010a), the number of features with specific value, and increases in real-estate value (e.g. Nowak and Dwyer, 2007). Regulating service indicators, such as assessments of air temperature regulation, removal of air pollutants and noise reduction, were also referred in some of the reviewed studies. For example, changes of temperature (Jim and Chen, 2008 and Tallis et al., 2011), air pollutants such as, NO_x, O_3, benzene, particulate matters and VOC (Zhang et al., 2014), and the amount of dB decreased by green elements (De Ridder et al., 2004), were used as indicators to assess the corresponding regulating services of urban green spaces. Biodiversity maintenance can be revealed by indicators of plant species and habitat continuity (e.g. Tzoulas and James, 2011 and Hermy and Cornelis, 2000).

Furthermore, attempts have been made to assess in a single study several or all factors including ecological regulation, biodiversity conservation, recreational services,quantity and quality, and planning of urban green spaces using composite indicators. For example, in order to assess the quantity, quality, use and planning, as well as the development and management of urban green spaces, the URGE (Development of Urban Green Spaces to improve the quality of life in cities and urban regions) project (2004) developed a detailed worksheet of criteria and indicators at both the city- and site level, including a set of unfolded indicators - shade area at noon, air quality, species diversity, frequency of use, number of entrance and number of parking places (Carlos Smaniotto Costa et al. 2004).

Baycan-Levent et al. (2009) developed a multi-dimensional evaluation method which considers the quantity, accessibility, changes and planning of green spaces. The indicators can be represented by e.g. the proportion of green space area per 1000 inhabitants, ten-year change in green space, and existing planning goals (Baycan-Levent et al. 2009). In another study, Stern (2010) developed a set of indicators, including both objective (e.g. stratification, vegetation density and proportion of evergreen vegetation for the assessment of air purification; vegetation coverage and tree proportion for the assessment of temperature regulation, and habitat size and shape for assessment of biodiversity) and subjective ones (e.g. local residents' assessments of the use and facilities of green spaces).

In summary, the indicators varied among different assessment methods. There is an increasing trend to develop and test ecosystem service indicators from a wide scale to a local/site scale (Layke 2009; Sparks et al. 2011). Researchers should analyze, monitor, and efficiently measure the conditions, characteristics, trends, and rates of change of ecosystem services in order to infer suitable indicators (Layke 2009; Sparks et al. 2011). However, the research is still faced with some difficulties and shortages. (1) The use of particular indicators depends on the availability of data and policy objectives. The indicators should be measurable, able to convey information, and be sensitive to change (Layke et al. 2012); (2) Some researchers use a single indicator or a number of connected indicators to evaluate a specific ecosystem service, wheras others use several indicators. While a single indicator is in most cases not sufficient for the assessment aims, several indicators sometimes provide overlapping information; (3) Since the indicators are used to reduce the complexity of assessments, they do not necessarily provide a comprehensive understanding of all services; (4) Numerous indicators and metrics of urban ecosystem services with different use quality and applicability are still conceptual in nature, and it has not been clearly demonstrated how exactly these indicators are linked to the underlying ecosystem services (Haase et al. 2014).

2.2.3 Processing the Indicators for the Assessment of Ecosystem Services Provided by Urban Green Spaces

Various models are used to evaluate the provision of ecosystem services, including empirical, GIS-based, statistical and survey-based models. A large number of studies have used empirical methods or models to quantify ecosystem services using different indicators. This is especially true for regulating services such as air pollution reduction and local climate regulation. However, models used for urban valuation need to be adjusted to the complex and multi-functional urban environment (Pataki et al. 2011). GIS-based models are useful for providing analyses because indicators based on spatial data, such as land cover and land use derived from maps are increasingly available. Consequently, aerial photographs and satellite imagery can serve as a basis for estimating particular ecosystem services associated with vegetation types and other landscape features. This method provides intuitive results, albeit suitable models are still needed (e.g. BUGS project, 2004; Onder et al., 2011 and Gupta et al., 2012).

Surveys are often used to analyze the recreational services provided by urban green spaces. In particular, questionnaire surveys can evaluate the use, activities, perceptions and preferences of the users of urban parks (Chiesura 2004; Tyrväinen et al. 2007). For example, in a visual quality assessment method, visitors were asked to rate a selected photo with conceptual parameters and physical features on a desirability scale as 1, 2, 3, 4, 5 (1 the lowest, 2 low, 3 medium, 4 high and 5 the highest). The final assessment was inferred by simply adding the total scores. This method takes users' appreciation and preferences as the basis, emphasizing both functional and visual satisfaction.

A number of studies assessed the ecosystem services by rating the ecosystem indicators according to their contribution to specific services, such as poly-functional assessment methods and multi-dimensional methods. In these studies, indicators were graded with scores or levels based on the amount, percentage, performance or ability (e.g. URGE project, 2004; Sandström, 2009; Stern, 2010). For example, in the poly-functional assessment method (PFAM) used in the URGE project, each indicator was given a score. Zero points indicated that the criterion cannot be fulfilled (e.g. water quality cannot be assessed if there is no water) (Carlos Smaniotto Costa et al. 2004). In practice, the ranging scales can be changed locally. Researchers can decide whether or not to apply weights to individual criteria according to the situation at hand. If a weight is applied, each indicator would be multiplied by its impact factor and the weight. Finally, the total score of all indicators under a criterion were aggregated to obtain the absolute functional values. The results were expressed per criterion in scores between 1 and 5. One point indicated that the criterion was very poorly fulfilled, and 5 points indicated that the criterion was fulfilled very well. Generally, the PFAM assessment method can be used for individual green spaces, and is adequate to compare several green spaces with each other. Also, the results of this assessment can be visualized per criterion via GIS, using the software ArcView (Carlos Smaniotto Costa et al. 2004). However, such methods are very time-consuming due to the large number of indicators involved, and are not suitable for indicators which cannot be ranked.

Stern (2010) designed similar procedures for assessing both objective and subjective indicators of ecosystem services. All the indictors were endowed with the same weight, and were ranked based on percentage, e.g. vegetation cover was rated as: low (0-35%), medium (36-70%) and high (71-100%) (Stern 2010). The remaining indicators were dealt with in a similar way, but with different percentage scales. For example, the tree proportion ranged between 0-25% (low), 26-50% (medium) and 51-100% (high) due to the varying impacts of each indicator's percentage on ecosystem services. The final assessment results were deduced via a pairwise comparison, and represented by the ranking of low, medium and high values.

In the multidimensional evaluation methods used by Baycan-Levent et al. (2009), quantitative indicators (e.g. ratio scales) were obtained from government departments and qualitative indicators (e.g. yes/no ordinal scales) were obtained from questionnaires. All criteria were assessed using a series of simple rules, e.g. "higher is better", "existence is better", "experience is better" and "increase is better". This collection of diverse indicators limits the applicability of quantitative analysis techniques and therefore calls for a regime analysis, which is based on a generalization of pairwise comparisons. If there was no prioritization of the criteria in the evaluation process, all criteria were assigned the same numerical weight value. Finally, the performances of green spaces were transferred into scores via the regime vector module, after which they could be ranked and compared. However, this multi-dimensional method requires a set of characteristic attributes and judgment criteria from a methodological perspective (Baycan-Levent et al. 2009).

The review of previous studies shows that a large number of indicators, criteria and models have been used for the assessment of ecosystem services generated by urban green spaces. Indicators were usually quantified (e.g. by percentage and amount, yes/no answer, or mentioned/not mentioned), and then endowed with scores to indicate their impact/value on ecosystem services of urban green spaces. The results of assessment were aggregated by summing up all the indicators, and then shown on maps in GIS software or calculated using modules. All these methods require the assistance of GIS software, since most of them used the data from remote sensing, and some rely on GIS software to visualize the results. Additionally, some assessment results were summarized by adding all the indicators and then averaged them using simple arithmetic means, or by pairwise comparison and transformation into categories such as qualified/unqualified, bad/moderate/good or low/medium/high.

The reviewed studies also suggest that the evaluation methods of urban green spaces can be comprehensive, integrated and multi-disciplinary, by using a combination of data from remote sensing, government departments, field surveys and questionnaires with the help of GIS, SPSS and module analysis. However, integrated valuation methods such as multi-criteria analysis need to be introduced to both local and regional planners.

2.3 Land Cover Mapping as an Assessment Tool for Regulating Services of Urban Green Spaces

2.3.1 Land Cover Types within Urban Green Spaces and Their Relation to Ecosystem Services

2.3.1.1 Definition and Classification of Land Cover

Since ecosystem services in urban areas are clearly directly related to land cover (e.g. MEA, 2005), a good understanding of land cover is required in order to plan and maintain ecosystem services. Land cover maps, which represent the dominant landscape cover in a particular area, offer a helpful tool to discern land cover types and hence the predominant ecosystem services.

Land cover can be defined as what can be observed on the earth's surface (Di Gregorio 2000), which results from past and present human activities and thereby leads to relatively stable features lasting for a long time (Pauleit and Duhme 2000). Land cover is the result of land use by changing the earth's surface. Land cover, and specifically vegetation change, is one of most sensitive indicators of environmental change such as deforestation, overgrazing and urbanization, and hence has a profound effect on the characteristics of ecosystems. Surface cover is a synonym for land cover, and is defined as the characteristics and elements of vegetation and/or built-up structures on earth's surface (Pauleit and Breuste 2011). A limitation of surface/land cover is that it only provides a two-dimensional representation of earth's surface.

Therefore, in this study, vegetation composition and layers will also be assessed to represent the vertical dimension.

New technologies for data collection and processing are currently available for land cover maps which offer considerable improvements over traditional methods. These new technologies include integrated remote sensing and Geographical Information System software. Remote sensing plays an important role in generating land cover information, not only due to its explicit spatial representation of earth's surface, but also due to its frequent temporal coverage and relatively low observation costs (Batista and Haertel 2010). More recently, the Google Earth (GE) tool has quickly been developed for applications in many fields. The high-spatial-resolution images released by GE have been used as a free and open data source for land cover classification and as a visualization tool for land cover maps (Mering et al. 2010). It has been proved that land cover classification based on GE images is not statistically significantly different from the classification based on QuickBird images (Hu et al. 2013). Moreover, GE imagery performs well for mapping land cover types with good spatial characteristics in terms of shape and context (e.g. road and river), and somewhat less so for grassland and woodland, which requires a high spectral signature (Hu et al. 2013). Considering this limitation, other ancillary data are suggested to be included to improve the classification accuracy of GE imagery, such as observation data from field surveys (e.g. Cornelis and Hermy 2004).

In addition, as the research aims vary, the use of data is either detailed or rough, and the sampling scale may be different, which leads to differences of classification of urban land cover. Almost all the research on land cover at the city level includes roads/transport systems, cemeteries, residential, industrial and commercial areas, car parks, agricultural land, water-covered areas, parks, woodland, and abandoned land (e.g. Di Gregorio, 2000; Pauleit and Duhme, 2000; Young and Jarvis, 2001; Akbari et al., 2003 and Livingston et al., 2003). At the site level, the present literature reveals that urban parks usually include buildings, pavements, open soil, vegetation and water (see Table 2.5).

The green-cover ratio, which is defined as the proportion of cover by vegetated surfaces in a given piece of land, are normally used as an indicator in urban planning in Chinese cities. In Pauleit and Duhme's (2000) classification, vegetation is subdivided into trees, shrubs, rough grass/ tall herbs, lawns and flower beds (see Table 2.5). Vegetation accounts for 80% of all land covers, and lawn is the predominant type, covering 80% of the vegetated surface area. Some researchers attempted to explore the vegetation in more detail. Sekliziotis (1980) categorized vegetation according to the delineation of grass type, e.g. turf grass, rough grass and infested grass (see Table 2.5). Young and Jarvies (2001) classified vegetation by taking into consideration its type (e.g. trees and lawns), distribution (e.g. trees and tree rows), as well as their height (e.g. tall herb vegetation and turf grass) (see Table 2.5).

Hermy and Cornelis (2000) saw the classification from a different perspective. They divided the habitat units of urban parks into planar, linear and point-like, according to their surface shapes. This classification has more detailed subdivisions, especially in terms of vegetation. For example, the planar elements were defined as including forests, planted trees and shrubs, crops and vegetables, fallow land, ponds, buildings, car parks, etc. (see Table 2.5). Furthermore, the forest category was subdivided into deciduous wood, coniferous wood and mixed wood. Later, in 2004, the authors simplified the classification based on the version from 2000, though the differences were not very large (see Table 2.5). It was observed in field surveys that woodland and individual trees occupied a large proportion among all the habitat types. Gao et al. (2010) took a biotope mapping approach to habitat classification (see Table 2.5). This classification is based on a maximum six-level hierarchal variable. The first level is the division of vegetation, open soil, water areas and sealed impermeable "hard surfaces", which include concrete, asphalt and construction such as buildings and pavements (see Table 2.5). The remaining levels all pertain to the variations of vegetation structure, which will be described in the next section.

Generally, the comparison of various approaches shows a broad array of land cover classifications, which provides a useful basis for later research (see Table 2.5). The land cover types of urban green spaces can be simply classified into three categories: concrete construction, vegetation and water. Concrete constructions usually include buildings, icehouses, roads, walls and pavements. Vegetation mostly includes trees, shrubs, grass, and lawns. No matter which classification was used, the planar elements, especially forests, trees and grasslands, accounted for the overwhelming majority of land surface area within urban green spaces.

Table 2.5 Examples of land cover units within urban parks (own drawing)

Land cover	Sub-divisions of land cover	Sekliziotis (1980)	Pauleit and Duhme (2000)	Hermy and Cornelis (2000)	Young and Jarvis (2001)	Cornelis and Hermy (2004)	Gao et al. (2012)
Built / Buildings		√	√	√		√	√
Icehouse				√		√	
Roads				√	√	√	
Walls				√	√	√	
Pavements / Concrete		√	√		√		√
Car parks				√			
Open soils		√	√	√	√		√
Vegetation	Forest			√		√	√
	Trees / planted trees	√	√	√	√		√
	Park-wood and orchard			√	√	√	
	Tree rows			√	√	√	
	Shrubs	√	√	√			
	Hedges			√	√	√	
	Lawn		√		√		
	Turf grass	√			√		
	Rough grass	√	√				
	Infested grass	√					
	Pasture			√		√	
	Grassland			√	√	√	√
	Hay meadow			√		√	
	Tall herb vegetation		√	√	√	√	
	Flower beds	√	√				√
	Vegetables	√		√			√
	Arable crops	√		√			
	Reed communities				√		
Water	Water / freshwater	√			√		√
	Bank			√		√	
	Pool			√		√	√
	Brook			√		√	

2.3.1.2 Relationship between Land Cover and Regulating Ecosystem Services

There are important differences between land cover types, such as impervious surfaces, water, groups of trees, shrubs, rough grassland, arable land and flower beds, in terms of providing ecological services such as removal of air pollutants, regulation of the microclimate, rainwater infiltration and surface run-off. Some studies have explicitly referred to this topic. For example, Carlson and Arthur (2000) used land cover changes to reveal the related changes of surface microclimate and hydrology. Janssen et al. (2008) estimated the air pollution based on land cover data, while Lehmann et al. (2014) used vegetation structure types as an approach for identifying micro-climate effects. All of these studies demonstrated that large areas of woodland and forest have obvious ameliorating effects on local microclimate, water run-off, and even air quality in urban areas.

Within a green space, temperature is affected by the proportion of vegetation, pavements and water bodies. Large vegetated areas bring about markedly lower temperatures than the surrounding buildings and pavements (e.g. Nishimura et al., 1998 and Ayman Hassaan Ahmed, 2011). For example, in Tainan, Taiwan, a study showed that at a scale of 100 meters, under the same environmental conditions, a 10% increase of vegetated surface reduced the temperature by 0.14-0.32 °C (Kuo 2000). Another study in Merseyside, UK, showed that the surface temperature at noon in an area with 50% of vegetation cover as around 7 °C lower than that of one with 15% vegetation cover among four sites (Whitford et al. 2001).

Conversely, impervious surfaces generate comparatively higher temperatures (Chi-Ru Chang et al. 2007; Weng and Yang 2004). Thus, the higher the proportion of impervious surface area, the higher the land surface temperature (Chen et al. 2006; Weng 2001). For example, in Taipei, Taiwan, Chang et al. (2007) found that, at summer noon, parks smaller than 3 ha with more than or equal to 50% of paved surfaces were on average warmer than their surroundings. Moreover, this effect increased with park size (Chi-Ru Chang et al. 2007). Temperature measurements in greater Manchester, UK, showed that concrete and asphalt surfaces in parks were some 18 °C warmer than the local air temperature (Armson et al. 2012). Therefore, it is possible to decrease the temperature of urban green spaces by reducing the paved area.

Water also plays a fundamental role in evaporative cooling in hot climates (Akbari et al. 2001; Givoni 1991b). Water features in parks come in different forms such as fountains, cascades, water channels, ponds and novel water facilities including waterfalls and spray fountains (Ayman Hassaan Ahmed 2011). A study of Tennoji Park in Osaka, Japan, showed that during the daytime, the maximum surface temperature was around 30 °C in the pond and 39 °C on the paved stone with a spray fountain, compared to a searing 50 °C on the paved area (Nishimura et al. 1998). The temperature measurements in eight sites within a park in Cairo, Egypt, showed that the air temperature increased by up to 4.7 °C going from tree canopies (32.5 °C), cascades (33.2 °C), fountains (35.3 °C), lakes (35.5 °C), hilltops (35.6 °C), resting areas (35.7 °C), and pavements (35.8 °C), to linear pathway (37.2 °C) (Ayman Hassaan Ahmed 2011).

Similarly, the regulation of air quality by urban green spaces is mainly mediated by vegetation. Accordingly, air quality improvements increase with increased percentage of tree cover and decreased mixing-layer heights (Nowak et al. 2006). Pollution in big cities is caused mainly by traffic emissions, which are attenuated within a 100-m-wide patch of vegetation (Gilbert et al. 2003). Accordingly, the pollutant concentrations showed a notable decrease from the outside to the interior of parks. A study in a park in Essen, Germany, measured the concentrations of NO, O_3 and NO_2 in different land cover types at varying wind speeds. The results demonstrated increased emissions of NO and NO_2 along green areas, residential areas, secondary roads and motorways (Kuttler and Strassburger 1999). A study conducted in 55 US cities found that in urban areas with 100% tree cover (i.e., contiguous forest stands), the average air quality improvements during the daytime of the in-leaf season were around 2% for particulate matter, O_3, and SO_2 (Nowak et al. 2006). In some cities, short-term air quality improvements (one hour) in areas with 100% tree cover were estimated to be as high as 16% for O_3 and SO_2, 9% for NO_2, 8% for particulate matter, and 0.03% for CO (Nowak et al. 2006).

2.3.2 Vegetation Structure Types within Urban Green Spaces and their Relation to Ecosystem Services

2.3.2.1 Definition and Classification of Vegetation Structure

A comprehensive classification of land cover is the basis for land cover mapping. However, most classifications have primarily been divided into land-use types and habitat types (see Table 2.5). Land cover types only offer information on the horizontal dimension, while vegetation structure concerns both horizontal and vertical information. Vegetation structure thus provides more detailed information on vegetated land cover. Characterizing the structure of vegetation is particularly important for assessing regulating ecosystem services such as microclimate moderation and filtering of air pollutants, as well as habitat and recreational quality of green spaces at the site level (Sandström et al. 2006).

For these reasons, the land cover classifications shown in Table 2.5 should be complemented with more detailed information on vegetation structures. Vegetation structure can be defined as "the organization in space of the individuals composing a vegetation type or association" (Dansereau 2011). In other words, vegetation structure refers to the composition and height variability of trees, shrubs and grasses in an area (Tzoulas and James 2010a).

Based on previous studies concerning vegetation structure within urban green spaces (e.g. Wittig, 1983; Hercock, 1997, Tzoulas and James, 2010 and Gao et al., 2012), the vegetation structure can be classified into trees, shrubs, and herbs-and-grasses (see Table 2.6). Without considering height, Witting (1983) divided up the vegetation mainly by spatial layout of trees, and classified it into rows of trees, groups of trees and single trees (see Table 2.6). Considering the vertical variations of vegetation, Hercock (1997) proposed a division based on the height ranges of trees, shrubs and herbs. Trees were thus classified into < 10 m, 10-30 m and > 30 m categories. Shrubs were divided into < 1 m, 1-2 m, and > 2 m, and herbs into < 5 cm, 5-20 cm, 21-50 cm and 51-100 cm categories (see Table 2.6). Later, Tzoulas and James (2010) adapted the height of trees, shrubs and herbs according to their local growth (see Table 2.6).

It is worth noting that Gao et al. (2012) identified the vegetation structure with more comprehensive factors including cover of trees and shrubs, age of the trees, and plant types and configurations (see Table 2.6). For example, areas with over 80% coverage by trees and shrubs were classified as forests, which were further described based on their layers as one-layered, two-layered and multi-layered (see Table 2.6). Within a forest, trees were divided by age into those of less than 30 years, 30-80 years, more than 80 years, and clear cut (Gao et al. 2012) (see Table 2.6). Even in the same age group, trees were subdivided into deciduous, deciduous and coniferous, coniferous and swamp categories.

In general, all the above-mentioned classifications considered the height variations of vegetation. An obvious feature in the study by Gao et al. (2012) is that plant types and configurations were considered in the course of classification. Such a way of classification provides much more information and details on the trees in the study area, and therefore helps to explore the relationship between biodiversity/recreation services and habitats. In this regard, a detailed characterization of vegetation is required to describe its influences on ecosystem services such as biodiversity, recreation, air quality and microclimate.

Table 2.6 Examples of vegetation structure types within urban green spaces (own drawing)

Type of vegetation structure	Subtype of vegetation structure						
	Wittig (1983)	Hercock (1997)	Tzoulas and James (2010)	Gao et al. (2012)			
Wood	Wood			Forest	< 30 years 30-80 years > 80 years Clear cut	Deciduous/ deciduous and coniferous/ coniferous/ swamp	One-layered/ two-layered/ multi-layered
Trees	Row of trees Group of trees Single trees	Trees (> 30 m) Trees (10 m - 30 m) Trees (< 10 m)	 High trees (≥ 10 m) Low trees (5 - 9.9 m)	Grove, clump of trees, thicket, tree belt or avenue	< 30 years 30 - 80 years > 80 years	Deciduous/ deciduous and coniferous/ coniferous/swamp	One-layered/ two-layered/ multi-layered
Shrubs	Hedges	Shrubs (> 2 m) Shrubs (1-2 m) Shrubs (< 1 m)	Bushes (1 - 4.9 m)				
Herbs and grasses	Herb plants	Grasses (51 cm - 1 m)	High grasses and forbs (20 - 99 cm)	Succession area			
	Hay meadow	Herbs (21 - 50 cm)		Meadow			
	Pasture	Sedges (5 - 20 cm)	Low grasses and forbs (5 - 19 cm)	Grazed land area			
	Lawn	Ground covers (< 5 cm)	Ground flora (≤ 4 cm)	Lawn			
	Reed communities						

2.3.2.2 Relationship between Vegetation Structure and Regulating Ecosystem Services

Vegetation composition

Vegetation composition and layers were found to have a significant influence on the regulation of microclimates and air quality. Multi-layered vegetation, in which tree-, shrub- and herb layers overlap, would promote the decrease of temperature and air pollution within green spaces, mainly by increased shading, evapotranspiration, and increased carbon uptake and storage per unit area (Armson et al. 2012; Souch 1993; Spronken-Smith and Oke 1998).

There are many studies on temperature regulation by urban green spaces. Generally, air temperature effects are smaller than surface temperature effects. In different urban parks in the USA, a temperature study of ten different parks in the summer indicated that the largest air temperature decrease at 1.5 m height was 5 °C in a park with a mixture of grass, trees, shrubs and flowerbeds, followed by around 4 °C above open grass and grass with large tree borders (Spronken-Smith and Oke 1998). Another study conducted in Bloomington, Indiana, USA, measured and compared the air temperature at 1.5 m height in three green environments: individual trees over grass, clumps of trees over grass, and individual trees over concrete. The results suggested that the cooling effect of groups of trees or individual trees over lawn was stronger than that of the individual trees over concrete. By evening, the latter were approximately 0.5 °C warmer than the surrounding areas (Souch 1993). Another study in Utah, USA, recorded the surface and air temperature data for three days in locations with vegetation over turf and over asphalt. The average air temperature and surface temperature of asphalt was 31.5 °C and 56.6 °C, which was 0.4 °C and 25.9 °C higher than over turf, respectively. Finally, the results demonstrated that trees planted into turf reduced the air temperature more strongly, since evapotranspiration rates were higher than those for trees over asphalt due to longer stomatal closure induced by higher leaf surface temperatures (Kjelgren and Montague 1998). Similar conclusions can be inferred from the research of D. Armson et al. (2012). They suggested that having both trees and grass would be even better than either alone, as the surface temperature of grass in shade can be 4-7 °C cooler than the surrounding air (Armson et al. 2012).

In China, a study of urban parks in Xi’an city showed that the air temperature at 1.5 m height at sites with trees over shrubs and lawns was on average 3.76 °C lower than at pavements, compared to a 1.54 °C reduction over lawns (Qin Yaomin 2006). A similar study in Zizhu Park, Beijing, showed that the three-day-average temperature decreased by approximately 2 °C with an increased quantity of combinations of trees and shrubs (Wu et al. 2006). Similarly, a study measuring the air temperature at 2 meters of height in- and outside of 61 parks in Taipei revealed that a higher combined cover of trees and shrubs correlated with cooler temperatures within the parks compared to their surroundings, especially at summer noon (Chi-Ru Chang et al.

2007).

In addition to temperature regulation, multi-layered vegetation, e.g. trees over shrubs and grass, have been suggested to possess a higher capacity for the reduction of air pollutants. Moreover, this effect is much more pronounced during summer under all conditions (e.g. Gromke, 2011; Nowak, 2006 and Wania et al., 2012). Air quality models which quantify the effects of plant-related functional attributes on pollution reduction are often based on relatively accurate estimates of vegetation structure (e.g. Gromke, 2011 and Wania et al., 2012). Vegetation structure influences the canopy area, which is a main determinant of the capacity for air pollutant removal.

The combination of trees and shrubs is important because planting bushes in or between trees is more effective in terms of pollution reduction than a forest of the same size (Heidt and Neef 2008). This may be due to the increased deposition of air pollutants (Cavanagh et al. 2009; Yin Shan 2007). A study monitoring the particulate matter in Riccarton Bush, Christchurch, New Zealand, explored the variations of particulate matter by vegetation structures. The results showed that the particulate matter at the monitoring sites with similar coverage of one/two-layered trees over shrubs ranged from 21.3 $\mu g/m^3$ to 23.1 $\mu g/m^3$ (Cavanagh et al. 2009). However, in areas with the same vegetation coverage but only a single tree layer, the particulate matter increased up to 31.9 $\mu g/m^3$ (Cavanagh et al. 2009). Similar results were obtained in a study of particulate air pollution concentrations in six green spaces in Shanghai, China by Yin Shan et al. (2007).

Tree Cover

In China, trees are usually defined as woody plants with a main stem higher than 5 m (Chen 1990). In different studies, the size of the crown area (C.L 2002) or the tree's canopy was considered as the most important factor for mitigating excess urban heat (Chi-Ru Chang et al. 2007; Shashua-Bar and Hoffman 2000; Weng and Yang 2004; Zhou et al. 2011), because trees absorb and reflect the biggest part, probably up to 80% of the solar radiation, by their dense crown (Gillespie 1995; Picot 2004). Solar radiation was thought to be the determining factor of temperature change, especially in the summer. Canopy shading is determined by tree height and size, foliage density, canopy volume, spacing of the trees, and growth factors such as cultivation and irrigation regime (Potchter et al. 2006; Shashua-Bar and Hoffman 2000). Moreover, trees can affect the temperature through transpiration, shading, altering the wind speed, and modifying the storage and exchanges of heat among urban surfaces (McPherson 1998; Nowak and Dwyer 2007; Spronken-Smith and Oke 1998; Weng and Yang 2004). Usually, one or more of these microclimatic factors of trees produces a high cooling efficiency. Therefore, it was suggested that more trees as opposed to grassy lawns and shrubs should be planted to moderate the air temperature.

Trees influence the microclimate at a range of scales, from an individual tree to a forest. The reduction of solar radiation induced by groups of trees is much greater than that induced by isolated trees (Andrade and Vieira 2007). For instance, based on modeling, increasing tree cover by 25% in Sacramento and Phoenix would decrease the summer surface temperatures by 3.3-5.6 °C (Akbari H. 1992). A land surface temperature measurement in Shah Alam City indicated that the temperature in groups of trees was on average 3 °C lower than in other vegetation (Buyadi et al. 2014b). By contrast, under the canopy of individual trees or small groups of trees, the reduction of air temperature amounted to only 0.7-1.3 °C compared with near-open space, at summer noon in Bloomington, Indiana, USA (Souch 1993). Therefore, increasing the tree canopy coverage can be considered as an effective method to reduce excess urban heat via vegetation management (Zhou et al. 2011).

Among trees, mature ones have the most stable cooling effects due to the large shaded area and large total leaf surface (Huang et al. 2008). According to empirical observations, such as those done by Hercock, 1997 and Tzoulas and James, 2010, mature trees or high trees can be simply defined as trees with a height of more than 10 m. A fact that mature trees with large crowns contribute 80% of the cooling effect in summer was corroborated by 1500 hours of temperature data from six partially shaded areas in an urban complex in Tel-Aviv, Israel (Shashua-Bar and Hoffman 2000). In fact, 80-85% of solar radiation in summer was neutralized by big trees with full leaf coverage (Andrade and Vieira 2007). Even an individual large tree can have a valuable effect on temperature reduction. For example, measurements in the suburbs of Sacramento showed that the air temperature under the crowns of mature trees was 1.7-3.3 °C lower than in adjoining areas without trees (Taha HG 1988). Even a 3.6 °C decrease of temperature during the summer daytime has been documented in the shade of a large single tree in Miami, Florida (JR 1989).

On very hot days, temperature measurements in Gulbenkian Park and the surrounding built-up areas in Lisbon, Portugal, showed that the lowest temperatures (30-33 °C) were found in those parts of the park which were under dense tree shade (Andrade and Vieira 2007). A study in the subtropical city of Gaborone, Botswana, showed that at noon, densely vegetated areas were up to 2 and even 5 °C cooler than surrounding sites (Andrade and Vieira 2007; Jonsson 2004). Moreover, the temperature changes among the measurement sites were strongly associated with their shade degree. Simply put: the higher the shade, the lower the temperature (Andrade and Vieira 2007; Jonsson 2004).

Similarly, a temperature comparison was conducted at three urban parks with different vegetation compositions in the city of Tel Aviv, Israel. The results showed that an urban park containing tall trees with a wide canopy had the maximum cooling effect during daytime, reducing air temperatures by up to 3.5 °C. By contrast, dense, medium-sized trees reduced the temperature by up to 2.5 °C. Remarkably, an urban park covered with grass and a few low trees can be warmer than the built-up area during the day (Potchter et al. 2006).

Trees have a stronger ability to abate air pollution than other vegetation types because the filtration capacity of vegetation increases with an increase of the leaf coverage per unit area of land (Givoni 1991b). In addition to their large canopy leaf surface area, twigs and branches create a rough surface that effectively mediates the removal of coarse particulate air pollution via a dry deposition process (Beckett et al. 1998). Furthermore, the air turbulence created by trees increases the uptake of air pollutants more than what was observed with shorter vegetation (Givoni 1991b). Usually, a large leaf area for shading and high effective transpiration together increase the mitigation of pollutant concentrations (C.L 2002). Therefore, the order of pollution removal efficiency of vegetation is suggested to be trees > shrubs > grass. It has been demonstrated that increased tree cover can lead to greater total pollution removal (Nowak, 1994; McPherson et al., 1997; Scott et al., 1998; Nowak et al. 2006; C.Y.Jim et al., 2007; Yin et al., 2011 and Paoletti et al. 2011). For example, in West Midlands County, a model called "fine resolution atmospheric multi-pollutant exchange transport", predicted that an increase of total tree cover from 3.7% to 16.5% would reduce average PM_{10} concentrations by 10%, from 2.3 to 2.1 $\mu g/m^3$. Similarly, in Glasgow, increasing the tree cover from 3.6% to 21% was predicted to reduce the PM_{10} concentration by 7%, from 1.26 to 1.17 $\mu g/m^3$ (McDonald et al. 2007). Moreover, tall vegetation can capture particles more efficiently from the air by dry deposition than low vegetation types (Gallagher et al. 1997; McDonald et al. 2007). In fact, the tree crown diameter and height are the two most important factors affecting the elimination of air pollution (C.L 2002; McPherson 1994). Therefore, dense and continuous cover with large trees will contribute more to the improvement of air quality than a cover of low trees (Jim and Chen 2008a).

For instance, large, healthy trees greater than 76 cm in diameter can remove 60 to 70 times more pollutants per year than smaller ones with diameters of about 8 cm (McPherson 1994). Mature woodlands are obviously better than low vegetation at removing gaseous pollutants, because their canopies have a much greater surface roughness than other vegetation types (Manning 1980), and their large leaf area can effectively control the dispersal of particulates for miles (Fowler et al. 1989). A measurement of seasonal pollutant concentrations in an urban park in Shanghai, which included SO_2, NO_2, and total suspended particulate (TSP), showed that in summer the percentages of SO_2 and NO_2 decreased with increasing tree crown volume and coverage. The tree crown volumes were calculated via the tree crown diameter and height in relation to the surface area of the plots. Finally, SO_2 removal efficiencies were reduced from nearly 30% to 10% due to a four-fold decrease of tree crown volume and coverage (Yin et al. 2011).

Evergreen Species

Air pollution removal by vegetation relies not only on tree cover, but also on the in-leaf season. Trees remove gaseous air pollution primarily by uptake via leaf stomata. The condition of the plants' stomata can therefore alter the plants ability to absorb air pollutants (Nowak 2002). Evergreen species that grow throughout the year can contribute more to pollutant removal than deciduous ones, since air pollutant removal occurs principally during the in-leaf season, and the increased length of the growing season with longer foliage retention can result in greater total pollution removal (Paoletti et al. 2011). This is especially important since in many Chinese cities the emissions of air pollutants are increased during the winter. The efficiency of air pollution removal by evergreen plants is therefore decidedly superior to that of deciduous species (Jim and Chen 2008a).

Based on data from 55 cities in the USA, Nowak et al. (2006) demonstrated that an increased in-leaf season of urban trees leads to greater total pollution removal because the greatest effect of urban trees on O_3, SO_2, and NO_2 occurs during the daytime of the in-leaf season, when trees are actively transpiring water (Nowak et al. 2006). Cavanagh et al. (2009) measured the concentrations of PM_{10} in a broadleaf evergreen urban forest plot in New Zealand. The results showed that the mean PM_{10} concentration of 31.5 μg/m^3 outside the forest was lowered to 22.4 μg/m^3 within it (Cavanagh et al. 2009). Manes et al. (2012) estimated the total removal of O_3 by the tree groups in Rome, Italy, for two years. They found that the great majority of O_3 was removed by evergreen broadleaves during the whole year, ranging from 0.002 to 0.049 Mg/ha, while in summer conifers cleaned the highest proportion of O_3. As a comparison, the O_3 removal by deciduous broadleaves ranged from 0 to 0.042 Mg/ha, which was significantly lower than that of evergreen broadleaves. Most notably, the O_3 removal in winter by evergreen broadleaves amounted to around 0.005 Mg/ha, compared with practically 0 Mg/ha by deciduous broadleaves (Manes et al. 2012).

2.4 Green Space Features and their Relation to Human Use and Perception

2.4.1 Human Use of Urban Green Spaces

There have been a number of studies on human use of green spaces in the past decades. Urban residents typically appreciate and actively use urban green spaces, albeit the time and frequency of use vary from site to site. Mornings and afternoons are the preferred visiting times during a day. Stay time per visit is relatively short e.g. no more than one hour. For example, in Singapore, 85% of the residents declared that they used a park at least once per week and mainly on weekends (Yuen et al. 1999). The time choice was similar to the findings in Bari, Italy, but only 58% of the respondents in the study were frequent park users (Sanesi and Chiarello 2006). In Guangzhou, China 70% of the citizens reported to be frequent park visitors, and morning and evening were the preferred times to visit (Jim and Chen 2006a). In Copenhagen, Afternoon and midday were the most preferred times of the day to visit. Most citizens (82.2%) visited green spaces several times a month, and 74.3% stayed for 15 - 60 min. (Peschardt et al. 2012). Similarly, in Germany, Chile and Spain, most citizens stayed no more than one hour per visit (Priego et al. 2008).

The distance to green spaces has been shown to be one of the most important factors that affect the frequency of use. A distance of 300 - 400 m, which corresponds to a 5 minutes' walk, is often regarded as the threshold for daily visits to green spaces. Beyond this distance, the number of visits declines rapidly (Coles and Bussey 2000; Derkzen 2012; Grahn and Stigsdotter 2003; Nielsen and Hansen 2007). Those green spaces closer to home and familiar to people are usually most welcomed by women and children (Bell et al. 2004; Coles and Bussey 2000; Grahn and Stigsdotter 2003; Jim and Chen 2006b). Nevertheless, other studies, such as Barbosa et al. (2007), Comber et al. (2008) and Kessel et al. (2009), showed that at least 90% of the respondents do visit green spaces within 900 - 1000 m, rather than 300 - 400 m, if convenient public transportation is available. Therefore, a workable distance or convenient access is generally considered an important factor for the use of green spaces.

Coles and Bussey (2000) reported that the characteristics of a green space, such as the size and conditions of facilities, the area of play grounds and the number of available benches, have effects on its use (Coles and Bussey 2000). Larger parks are more frequently visited than smaller ones because of the abundant provision of various kinds of facilities and features (Coles and Bussey 2000; Jim and Chen 2006a; Rydberg and Falck 2000). However, well-designed small green spaces were perceived as more popular than the larger ones (Forsyth 2003). Some studies deemed that gender, income and education also affect the usage of urban green spaces, though the influences were complex and very location-dependent. For example, young and middle-aged citizens were found to be the main park users in studies by Yuen et al. (1999), Sanesi and Chiarello (2006), and Dunnett et al. (2002). However, similar studies by Jim and Chen (2006 b) and Toftager et al. (2011) showed entirely opposite results.

2.4.2 Recreation Activities in Urban Green Spaces

Citizens' recreation activities in urban green spaces are the basis for understanding the recreation services of green spaces, and thus provide information for the management, design and maintenance of urban green spaces. Recreation can be divided into two broad categories: active and passive recreation. Active recreation encompasses activities in which people are physically active and mobile, that can be done individually or in groups (Burgess 1988; Ho 2005). Passive recreation encompasses activities that provide visual, emotional, socializing or relaxing enjoyment, and include mostly stationary activities that are investigative and acquisitive in nature (Burgess 1988; Ho 2005).

People therefore make various use of green spaces, including a number of active activities such as exercising, jogging, bicycling, walking, waking the dog, playing games and doing sports, as well as passive activities such as dating, resting, getting fresh air, sightseeing, relaxing, enjoying and watching nature, or social contact and interaction (Burgess 1988; Chiesura 2004; Dunnett 2002; Yuen et al. 1999). These activities in parks are also a reason why people visit parks. Consequently, the more activities a park offers people, the more reasons and opportunities people will have to go and participate in these activities, meaning that park use will increase. Interestingly, people in developed and developing countries engage in similar activities in parks. For example, in the UK visitors went to green spaces mainly for walking, dog-walking, playing with children, sitting to relax and enjoy nature, and exercising (Dunnett 2002; Tzoulas and James 2010b). Similarly, visitors in Guangzhou, China inclined to go to green spaces for relaxation, staying in a peaceful place, physical exercise, nature appreciation and aesthetic pleasure (Jim and Chen 2006a). By contrast, in Beijing, China, the young respondents preferred to go to green spaces for walking, sightseeing and jogging (Zhang et al. 2015). There were also other preferred activities in green spaces, such as to have fresh air in Bari, Italy, (Sanesi and Chiarello 2006), or to encounter wildlife and to enjoy natural landscapes in the UK and Sweden (Grahn and Stigsdotter 2010; Özgüner and Kendle 2006). In reality, the combination of the above activities is what makes well-designed urban green spaces particularly attractive. Therefore, urban green spaces with a variety of facilities and features will be more popular, better known and more frequently visited (Grahn and Stigsdotter 2010).

Despite the large number of common uses, people from different social groups use green spaces differently. In fact, age, gender, race, education, employment and residence all appear to influence visitors' activities in urban green spaces. For example, researchers who have compared participation by age found in general that as the age of visitors increased, their participation in outdoor recreation and physical activity decreased. Especially, with visitors' increasing age there is a decline in the preference for participation in physical activity (Burgess 1988; Chiesura 2004; Dunnett 2002; Yuen et al. 1999). Sports and meeting others were pursued more by the young, while relaxing, being with children and enjoying nature appeared to be the preference of adults and the elderly (Chiesura 2004). In addition, males typically chose urban green spaces for sports, which was not the case for females (Sanesi and Chiarello 2006). Females usually engaged in stationary activities that are associated with childcare and family groups (Sanesi and Chiarello 2006).

The amount and quality of green spaces can affect the patterns of residents' activities, frequency of everyday recreation, and the way in which knowledge about the environment is acquired (Herzele and Wiedemann 2003). Larger green spaces attracted more physical activities (Qiu and Nielsen 2015). Access is also particularly critical for the recreational use of green spaces. Proximity will increase the recreational activities in green spaces due to less time being available in today's society (Coles and Bussey 2000). Indeed, having green spaces nearby in the neighborhood has been shown to increase outdoor recreational activities (Grahn and Stigsdotter 2003; Toftager et al. 2011).

Moreover, vegetation has been shown to be one of the characteristics that influence recreation. Trees and grass might foster daily activities and experiences important for children's development (Taylor et al., 1998). In urban parks of US cities, grass is positively associated with relaxation and rest, indulging, eating, play and reading (More 1985). By contrast, shrubs are negatively associated with most activities. Their very presence reduces the space available for activity, but the effect is not strong as the correlations are neither large nor significant (More 1985). Trees have interesting effects in two dimensions - number and size. The number of trees is positively correlated with many activities, but especially with sleeping and reading, likely since these two activities may occur in the shade. Large trees fostered conversing, play, reading and sleeping (More 1985). Preferences for such "green exercise" may result from being physically active and directly exposed to nature (Pretty et al. 2005). After all, doing exercise along with others (even strangers) while enjoying beautiful scenery and perhaps fresh air, is a desirable thing in itself for most people (King et al. 2000). For example, women in New York felt more fulfilled when undertaking exercise in the prospect Park than in other places, e.g. streets and indoor gyms (Krenichyn 2004). Furthermore, parks were identified by runners as a more restorative environment than city streets or sidewalks (Bodin and Hartig, 2003). Notwithstanding, how respondents' preferences for recreational activities can be influenced by different vegetation structures, such as vegetation types, layers and compositions, still needs further consideration.

2.4.3 Respondents' Perceptions of Urban Green Spaces

Perceptions are an important factor which determines the use of urban green spaces, and they are also the basis for assessing them. Perception is the gathering of information through the senses including seeing, hearing, touching, tasting, and smelling (Dawes 1972). Characterizing individual park users' perceptions can better support the integration of all interested groups, optimize local benefits, and increase success in community and green space planning by using cooperative management strategies (Gerd 2002).

Measuring respondents' perceptions towards urban green spaces has been mostly done through structured questionnaire surveys (Balram and Dragicevic 2005). In some studies, respondents ranked visual aesthetics and shading as the most important values of green spaces (Lorenzo 2000; Wang et al. 2016). A survey of urban forests in Finland showed that residents commonly thought the social values such as outdoor activities and exercise to be important, while the benefits associated with environmental quality, such as wind protection, pollution mitigation and climate regulation were perceived as of relatively low importance. Economic values, such as timber production, were considered rather unimportant (Tyrväinen 2001). Similar research in Guangzhou, China also supported such findings. People appreciated more the recreational function of green spaces and their contribution to the improvement of the environment. In comparison, their functions as wildlife habitats and their economic value attracted little attention (Jim and Chen 2006a). However, the respondents in Bari, Italy and Phnom Penh, Cambodia considered the function of climate improvement more important than leisure (Sanesi and Chiarello 2006; Yen et al. 2016). Thus, outdoor recreation and aesthetic qualities are generally widely highlighted, and economic values of urban green spaces are ranked relatively low.

Common perceptions of urban green spaces can be linked to different societal and personal attributes. While nature-related benefits (e.g. wildlife habitat) were highlighted in the USA (Lorenzo et al., 2000) and northwestern European cities (Tyrväinen, 2001 and Tyrväinen et al., 2007). Climatic (e.g. shading) and environmental contributions (e.g. air pollution reduction) received the most attention in China (Jim and Chen, 2006a) and Italy (Sanesi and Chiarello, 2006). Some studies revealed that personal backgrounds particularly influence the perception of urban green spaces. A study in Guangzhou, China showed that younger (<30 years old) and richer residents (> RMB 3000/month) were more likely to emphasize the importance of ecosystem services generated by green spaces (Jim and Chen 2006a). In Bari, Italy, the climatic function of urban green spaces was particularly identified by males over 65 years of age (Sanesi and Chiarello 2006). Regarding urban green spaces as places for socialization and leisure was more prevalent among the younger of both genders, while seeing them as places for children to play in was favored by women (Sanesi and Chiarello 2006). By contrast, in Helsinki, Finland, women paid more attention to recreational and health benefits than other groups (Tyrväinen et al. 2007).

While residents have common perceptions of green spaces, differences were found across different study areas and social groups in the reviewed studies, because perceptions are usually affected by a joint effect of social, cultural, environment and personal factors in particular societies. Such differences still need further research in order to provide suitable green spaces for each group of users. For this purpose, it is important to carry out detailed surveys, interviews and observational studies, so that more in-depth insights can be acquired on people's behavior, preferences and perceptions. In practical policy makings, common perceptions are relatively easy to meet. However, the individuality of social groups remains a challenge for green space management.

2.4.4 Respondents' Preferences for Urban Green Spaces

Urban green spaces with their natural features such as trees, water, flowers and grasses are predominately welcomed (Yuen et al. 1999). Residents in East Midlands, UK declared they wanted a more natural appearance of urban green spaces (Bell et al. 2004). In the USA, half of the residents appreciated flowers and vegetation at parks (Pincetl and Gearin 2005). By contrast, water features such as streams and rivers were found to be highly preferred in the studies by Dwyer et al. (1989) and Rydberg and Falck (2000).

Apart from natural elements, people share an appreciation for other features of urban green spaces. They usually prefer peace, quiet and cleanliness in urban green spaces (Jim and Chen 2006b; Tyrväinen et al. 2007; Yuen et al. 1999). Some wanted more children's playgrounds, athletic fields and shelters (Özgüner and Kendle 2006). Some asked for more recreational facilities, such as tables, benches and drinking water (Herzele and Wiedemann 2003; Oguz 2000). Furthermore, some respondents wanted more species of vegetation, playgrounds and recreational activities provided by green spaces (Yen et al. 2016). Moreover, visitors from different gender and age groups may have different demands for urban green spaces. For example, green spaces closer to home were most welcomed by women and children (Bell et al. 2004). Last but not least, convenient public transportation was highlighted by the elderly in some cases (Jim and Chen 2006b; Sanesi and Chiarello 2006).

In summary, the literature review in this section reveals that a majority of the studies addressing the respondents' use habits, recreational activities, perceptions, assessments and anticipations of urban green spaces were conducted in developed countries or cities, particularly in Europe and North America, and few similar efforts were made in developing countries. Citizens' use behaviors, perceptions and expectations are rarely taken into consideration in the planning and management of green spaces in developing countries. During the city-construction history of China, policymakers seldom enquired the public's preferences and opinions. Consequently, urban green spaces may fail to meet consumers' demands, prevent certain groups of people from using them, attract undesirable elements or activities, and in extreme cases, be abandoned by users (Burgess 1988). In order to fill this research gap, more studies need to be conducted in developing countries that face high pressures in the conservation, provision and development of urban green spaces. Conversely, engaging citizens in the planning and management of urban green spaces can bring more benefits to more people (Dunnett 2002; Marcus CC 1998). In China, economic growth and increased public awareness of social affairs has created a need to consider public perceptions during the planning and development of urban green spaces. As new green spaces will be built and old parks with outmoded design need renovation, the government should incorporate citizens' preferences and expectations into decision making (Lorenzo 2000).

2.5 Ecosystem Services as an Approach to Support Green Space Planning

A high speed of urbanization leads to dense cities and land use competition, and under land use pressure, the planning of green spaces is always secondary to commercial planning. However, with increasing awareness of the importance of green spaces for sustainable development, the status of urban green spaces in urban planning has been raised, especially from ecological, cultural and economic perspectives (Baycan-Levent et al. 2009; James et al. 2009). The concept of ecosystem services is new and unfamiliar to many actors in green space planning, although the issues encompassed by the concept have been included in urban planning principles based on sustainable development. Introducing the concept could therefore help promote the development of a more comprehensive understanding of ecosystem services in the minds of civil servants, decision makers and citizens alike (Niemelä et al. 2010).

Generally, five principles that can be considered in green space planning were repeatedly described in the literature: (1) Accessibility for the public will increase the green spaces' attraction and use (Grahn and Stigsdotter 2003; Nielsen and Hansen 2007); (2) Coherence and sufficient size of green spaces can increase the ecosystem services, even if some ecological benefits can be provided by well-managed green spaces of limited size (Tratalos et al. 2007); (3) Variation in character and type of green spaces provides better functions - e.g. natural, recreational and well-kept parks with vegetation and wetlands (Gill et al. 2007; McPherson et al. 1997; Nowak et al. 2006); (4) Distribution of green spaces influences the quality of their ecosystem services, e.g. public parks, quiet places and fresh-air-generating zones which are located in high-density residential areas may enhance the provision of recreation and clean air (Givoni 1991b; Heidt and Neef 2008); (5) Public participation is encouraged in the process of green space planning. Involving the public in decision making is a driving force for the acceptance and implementation of green space planning (Li et al. 2005). Practitioners, researchers and politicians should deal with the issues of the entire planning process of urban green structure through a communicative process.

In order to enhance their ecological functions, urban green spaces should be viewed in an interconnected way with consideration of their size, diversity and distribution within the city, their history, as well as the design and management of individual green spaces (Gilbert 1989). The interconnection of all types of green spaces within a city was termed green space structure (Kaliszuk and Szulczewska 2005). Therefore, green spaces should be considered as an organized structure rather than many individual amenities. Every city has its own distinctive type of green space structure that results from the interaction of certain natural and human processes (see Table 2.1). Based on the origin and functions of green spaces, three layers of green structure can be identified: (1) The layer of natural landscapes that were there before the city came into existence. This includes forests, wetlands and arable land; (2) The urban layer or the amenity green structure. This layer includes public parks, residential, industrial and commercial green spaces, and city squares; (3) The linear layer, such as roads and green buffers (e.g. Kendle and Forbes 1997).

The ecological perspective is increasingly being applied to the study of urban green space planning. The corresponding studies provide valuable indicators of the ecosystem services generated by urban green spaces (as described in previous sections), as well as approaches that may optimize these services, such as the planning concepts of green belts (e.g. Bo et al., 2011), green corridors (e.g. Hellmund and Smith, 2006; Jim and Chen, 2003), green wedges (e.g. Li et al., 2005) and green infrastructure (e.g. Pauleit et al., 2011). For example, in some European cities, such as Helsinki and Oslo, green space corridors were planned for multiple social and ecological functions, including recreation, biodiversity conservation and ventilation (e.g. Bednarek, 1990; Blazejczyk and Kuchcik, 2001, Werquin et al., 2005). The contribution of woodlands to the reduction of air pollution from roads was explored, and detailed guidelines for the design of tree belts along the roads were developed (e.g. Beckett et al., 1998). Additionally, some studies discussed the relationships between green space structure planning and climate regulation, such as the ones conducted in Munich (Pauleit and Duhme, 2000) and Warsaw (e.g. Szulczewska and Kaliszuk, 2003). A green-finger design was considered to concentrate the climatic function of green spaces in the case of Warsaw (Szulczewska and Kaliszuk, 2003). In developing countries such as China, such studies mainly focused on a small number of large metropolitan regions. For instance, Jim and Chen (2003) applied landscape ecological principles to the planning of green spaces in Nanjing, China. Li and Wang (2003) proposed a method for the evaluation, planning and prediction of ecosystem services of urban green spaces in Yangzhou City in China, using landscape principles. In Beijing, the riverside green corridors can be used to create recreational open spaces for people with easy access, and encompass a variety of plant species, textures and colors. Roadside trees can separate the traffic line and reduce the noise. Moreover, their combined network can act as a green corridor for wildlife. For green space structure planning, the "star" settlement structure managed to connect green wedges (urban parks, urban forests and agricultural land) with green corridors (road trees and riverside trees) to reduce the heat island effect and enhance air ventilation (Li et al. 2005).

The above planning approaches consider urban green space as an integrated structure and attempt to optimize many of the functions of urban green spaces. Indeed, many of these functions are often interconnected. For example, a well-connected green structure can help protect, improve and create ecological corridors that enable plants and animals to move between core habitat areas. This may provide a better chance of survival for vulnerable populations (Tjallingii 2005). Combining green and blue (i.e. water) structures will improve both sustainable water management and the quality of green spaces for recreation (Tjallingii 2005).

This literature review indicates that planning practices of green spaces in dense cities need to permit the inclusion of urban green spaces that are close to people, coherent and of sufficient size, varied, well-maintained, and are places where people can engage in development. These rather general and non-quantified quality guidelines may serve to provide various ecosystem services, benefits and values, but will need to be adapted to site-specific conditions as a prerequisite for functional densification (Berg et al. 2012). Moreover, detailed information on ecosystem services of green spaces is still lacking, and its application in green space structure planning has not yet been discussed in detail, especially in developing countries. Therefore, more integrated green space planning and management practices are required to meet the ecological and current social demands in environments under strain. More detailed targets and goals of green space structure planning should be established using ecosystem service approaches and considering the interactions between different ecosystem services and green space structure planning. More research is needed to further understand which properties and potentials of urban green space structure can provide urban ecosystem services in dense cities.

2.6 Research Questions

The overview presented above shows a number of themes of ecosystem services provided by green spaces, including their definitions, classifications and various assessment methods. Beyond these research achievements, several open questions and research gaps, such as multidimensional assessment methods and incorporation of peoples' assessments into green space planning, need to be highlighted and explored further. The focus of this work therefore is the development of integrated assessment methods for ecosystem services using land cover mapping and visitors' questionnaire surveys, and the connection of ecosystem services to green space planning and development.

The research questions themselves are split into three related sections: the assessment of regulating services, assessment of recreational services, and green space planning and development. Each of these is first discussed as an independent issue, and then collectively to show the relationships between them.

Although the thesis reviews a number of assessment methods for ecosystem services, rapid and simple assessment methods using land cover types as assessment indicators are still needed in the context of limited data and time. The review presented in this chapter leads to the following research questions which further detail the aim and the four objectives of this research as outlined in chapter 1.3.

Objective 1: Develop and apply approach for the assessment of ecosystem services provided by urban green space.

Based on this objective, the corresponding research question is proposed - How can land cover and vegetation structure mapping be applied with a rapid and simple approach to assess the regulating services of urban green spaces in Xi'an city?

Objective 2: Identify the relationship between park features and ecosystem services.

Two questions were proposed in order to achieve objective 2.

Question 1. How does land cover influence the regulating services of green spaces in Xi'an city? For example, what are the main land cover types which influence the regulating services of green spaces, and how do they influence the regulating services?

Question 2. Which other factors (e.g. park area, age and location) also influence regulating services, and how?

Objective 3: Assess urban park use, perception and appreciation of ecosystem services by park users.

In this study, these basic questions were asked first to determine the people's use, assessments, demands for, and perceptions of green spaces. The most important research questions which needed to be answered here are the relationship between land cover types and peoples' use and assessment of green spaces. This new perspective links land cover types with recreational services, and hence fills the research gap:

1. What are the people's use habits, preferred recreational activities, demands for, and perceptions of green spaces in Xi'an? What are the predominant factors which influence peoples' use habits, preferred recreational activities, demand for and perceptions of green spaces?

2. How do users assess green spaces in Xi'an, especially the regulating and recreational services? What are the predominant factors (e.g. land cover types, green space characteristics and socioeconomic variables) that influence these assessments?

Objective 4: Explore how green space planning and management can better contribute to enhancing ecosystem services in Chinese cities.

Ecosystem services of urban green spaces and urban green space planning and development have been separately paid attention for many years. However, their combinations, such as considering ecosystem services in green space planning and development, still remain to be investigated in many developing cities such as Xi'an. The following questions will therefore be used to attempt to answer how to use the assessment of ecosystem services to achieve better green space planning and development:

1. How are the urban green spaces planned and developed in Xi'an? Are ecosystem services taken into account in the planning and management of parks in Xi'an city?

2. What are the main problems and critical issues for urban green space planning and development in Xi'an, both at the city and site level? How can the problems in urban green space planning and development be mitigated using the ecosystem services approach?

3 Materials and Methods

3.1 Study Area

3.1.1 Definition

As one of the strongly developing large cities in China, Xi'an has experienced massive land use changes from non-urban to urban, accompanied by the degradation of environmental conditions. At the same time, the awareness of important benefits of urban green spaces has increased. Some improvement approaches have been used to conserve the existing and develop new green spaces in the urban area. However, urban green space design, planning and development often lack a scientific basis and rationale. Moreover, the idea of solving local environmental and ecological problems using urban green spaces is seldom promoted. These circumstances make Xi'an a suitable area to conduct research aiming at better planning and conservation of green spaces.

The study area is confined to the central parts of Xi'an city. Given the high population density, rapidly developed economy, crowded urban fabric, deteriorating environment, and urgent expectations for a higher quality of life, it is warranted to conduct a scientific study of the urban green spaces of the city to inform better planning, management and conservation. The studied central area is located within the Third Ring Road, covering an area of 403 km^2 with a population of 4.5 million (XUPB 2010). The 22 urban public parks within this area were chosen as the research sites of this study (see Table 3.1 and Figure 3.1). Among these parks, one is a children's park, one is a sports park, and three are municipal parks. The remaining seventeen are all district parks.

3.1.2 Geographic Conditions

Geographically, Xi'an is situated in the middle of the Guanzhong Plain, which is a flood plain created by eight rivers and streams in Central China, located around 33°39'-34°45'N latitude and 107°40'-109°49'E longitude (XUPB 2010). The elevation of the study area is on average 412 meters above sea level. The Li Mountain lies east of the city and the Qinling Mountain to the south. The Feng River runs through the west of the city while the Wei River traverses the north. The distance from the east to the west of Xi'an is 204 km, and 116 km from south to north (XUPB 2010).

Influenced by the East Asian monsoon, Xi'an has a semi-moist temperate continental climate, which is characterized by brief and dry springs and autumns, hot and humid summers, and cold and dry winters. The average air temperature is 15.5°C annually, and reaches its lowest in January at -0.9°C and its highest in July at 26.4°C (XAALADI 2009). The annual average rainfall is about 600 mm, most of which falls from August to late October (XAALADI 2009). Dust storms often occur during March and April as the city rapidly warms up. In the summer months, there are frequent but short thunderstorms, and in winter, snow occurs occasionally but rarely settles for long.

The area hosts a large number of vegetation types. Before urbnization, the natural vegetation was bushlands, meadows, coniferous forests, mixed forests of conifers and borad-leaves, and deciduous broad-leaf forests (XAALADI 2009). Some species from natural habitats have been preserved in the urban environment. For example, relic species of the ice age, such as *Ginkgo biloba*, *Cercidiphyllum japonicum*, and *Tetracentron sinense*, have survived in this area. Since the 1850s, a number of exotic species have been introduced and widely planted, such as *Platanus spp.* and *Quercus variabilis*. At present, the city region contains more than 2200 plant species, among which approximately 1550 are spermatophytes (XAALADI 2009).

Table 3.1 List of the 22 investigated parks (source: Xi'an Ancient Architecture and Landscape Architecture Design Institute, 2009)

Park	Area (ha)	Recorded area (ha)	Year built	Green space type
Children's Park	2.11	3.0	1928	Children’s park
Tu Men Road Park	2.79	2.8	1997	Roadside park
Fang Zhi Park	3.44	3.0	1978	Neighborhood park
Ci En Si Yi Zhi Park	4.43	4.5	1997	Neighborhood park
Xi Qu Da Guan Yuan	4.44	4.2	2001	Neighborhood park
Lian Hu Park	5.25	6.4	1916	Residential park
Min Su Park	6.01	5.2	2001	Residential park
Xin Ji Yuan Park	6.05	6.0	1997	Residential park
Wen Jing Park	6.25	7.6	2004	Residential park
Mu Ta Si Park	6.31	6.8	2009	Residential park
Mu Dan Yuan	6.95	7.0	2007	Residential park
Lao Dong Park	7.33	7.7	1965	Residential park
Ge Ming Park	7.75	10.4	1927	Residential park
Huan Cheng Xi Yuan	10.96	10.5	2004	District comprehensive park
Yong Yang Park	11.24	11.7	2006	District comprehensive park
Chang Le Park	17.16	19.6	1977	District comprehensive park
Feng Qing Park	22.52	21.1	2004	Municipal comprehensive park
Qu Jiang Tang City Wall Park	31.99	31.0	2008	District comprehensive park
City Sports Park	33.84	35.4	2006	Sports park
Tang Yan Road Tang City Wall Park	40.57	44.4	2006	District comprehensive park
Xing Qing Park	48.99	50.2	1958	Municipal comprehensive park
Qu Jiang Yi Zhi Park	50.67	53.0	2008	Municipal comprehensive park

(Note: data of recorded park areas are taken from the field survey)

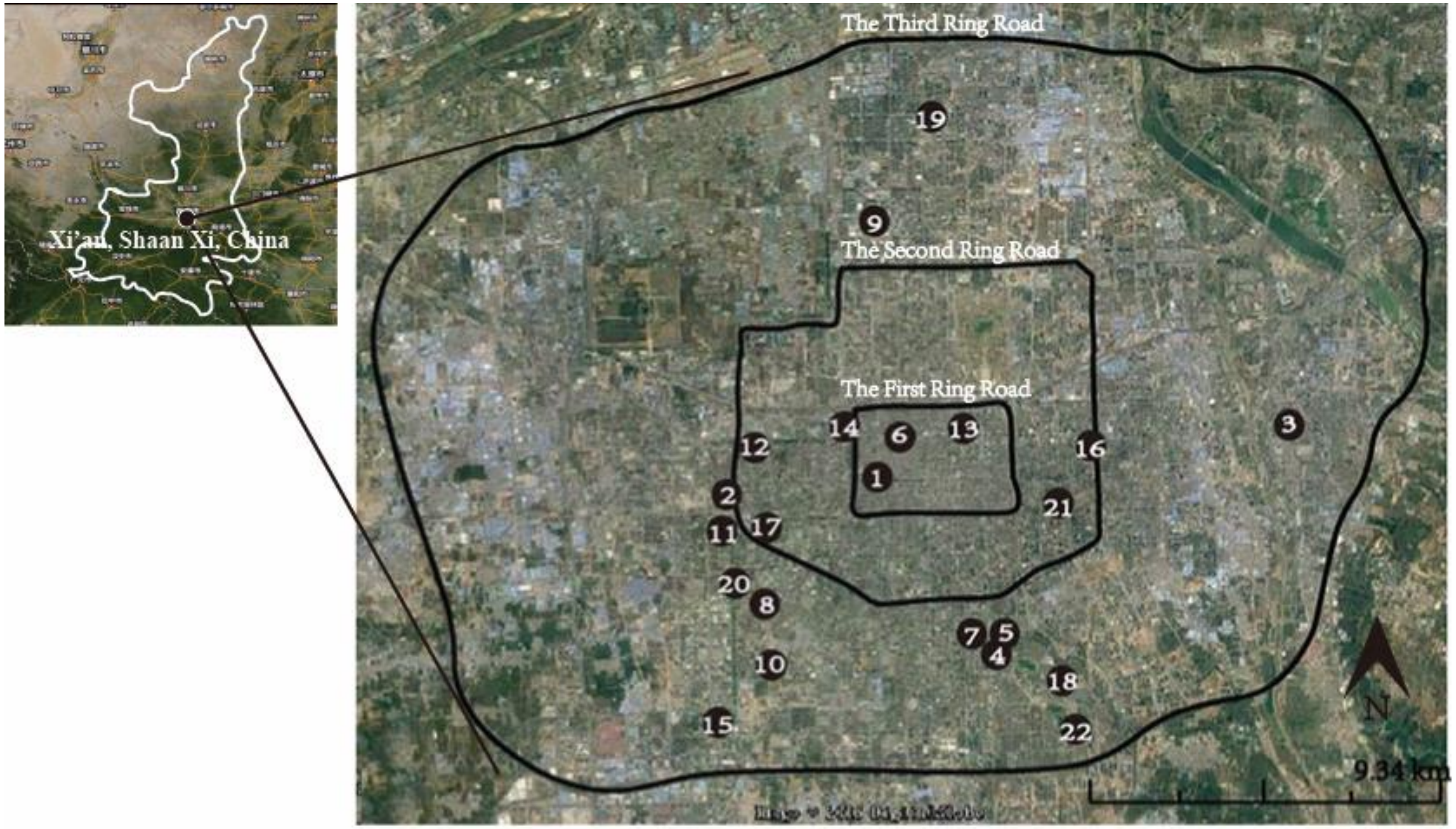

Figure 3.1 Site map of Xi'an and the 22 surveyed sites (own drawing)

1. Children's Park; 2. Tu Men Road Park; 3. Fang Zhi Park; 4. Ci En Si Yi Zhi Park; 5. Xi Qu Da Guan Yuan; 6. Lian Hu Park; 7. Min Su Park; 8. Xin Ji Yuan Park; 9. Wen Jing Park; 10. Mu Ta Si Park; 11. Mu Dan Yuan; 12. Lao Dong Park; 13. Ge Ming Park; 14. Huan Cheng Xi Yuan; 15. Yong Yang Park; 16. Chang Le Park; 17. Feng Qing Park; 18. Qu Jiang Tang City Wall Park; 19. City Sports Park; 20. Tang Yan Road Tang City Wall Park; 21. Xing Qing Park; 22. Qu Jiang Yi Zhi Park

3.1.3 Social, Economic and Environmental Conditions

Xi'an, the provincial capital of Shaanxi province, is well known for its rich historical and cultural resources. It was the capital of thirteen dynasties for over 3,000 years of Chinese history and was once the largest city in the world, during the Tang dynasty. Xi'an is also the political, economic, cultural, scientific and technological center of northwest China. Lying at the crossroads of several main inland arteries, Xi'an holds a powerful position among the central and western Chinese cities, and has an abundance of high-tech and light industries, universities and research institutions (XUPB 2010; Yongming et al. 2006).

The social development of Xi'an is supported by its economic development, and both jointly enhance the quality of life. After the implementation of reforms and the opening-up policy of the country in 1978, the economy of Xi'an grew consistently with an increasing speed over the last two decades. The yearly gross domestic product (GDP) growth rate has constantly surpassed 13% since 1995. As of 2011, the GDP of the city was 386,421 billion yuan (Xi'an Statistical Yearbook 2012, http://tjj.xa.gov.cn/ptl/index.html).

Accompanied by the rapid population growth and economic development, the urban area gradually expanded from the inner city-wall area, namely the built-up area enclosed by the ancient city wall, to the outside area, which can be divided by the three ring roads. In 2010, Xi'an had a population of 9.2 million and a total area of approximately 10108 km^2 (XUPB 2010). The inner area spans approximately 12 km^2 with a high population density of 36,885 persons/km^2. This is where the main commercial and political center of the city is now located, housing 37% of retail and 25% of commercial offices (Xi'an Statistical Yearbook 2010). Because of the numerous businesses, houses and institutes, this area contributes a large portion of the total GDP of the city. However, such achievements in economic development and urbanization have created serious congestion problems. As a result, the government had to relocate the commercial center to northern Xi'an, starting in 2004 (XAALADI 2004). Urban land use expanded continually from the city core to the periphery, changing the suburbs into urban areas. Especially after the 1990s, the city has enlarged rapidly, and the urban scale and structure have changed dramatically. Worryingly, a significant amount of arable land has been irreversibly taken over by businesses and industry (Lu and Peng 2006).

In addition, fast social development, economic growth and urbanization have brought a number of environmental problems to Xi'an. The climate of Xi'an has changed in the last 60 years (1951-2013), whereby the mean temperature increased by 1.3°C in the urban area - twice as much as the average global temperature increase (Che Huizheng 2005; Mengtao and Zhou 2016). Annually, the average temperature at noon is above 30, 35 and 40°C for 75, 20 and 7 days, respectively (Li 2002). Moreover, between 1993 and 2013, the average difference of air temperature between the suburban and urban areas was 0.35°C and 0.4°C in the hottest month - July (Liu 2008; Mengtao and Zhou 2016; Yufeng Liu et al. 2015). The intensification of the urban heat island phenomenon is thus obvious. Especially, between 2007 and 2012, the increase of air temperature due to the urban heat island effect was 1.06°C on average (Yufeng Liu et al. 2015).

Furthermore, one of the factors leading to the urban heat island effect is the decreased air humidity due to the large areas of hard/impervious surfaces in cities (Memon et al. 2011; Oke 2011). Vegetation, and especially tree species with high transpiration rates and water use efficiency can increase air humidity. Considering the prolonged periods of low temperatures in the winter months, large amounts of deciduous broad-leaf tree species are superior to other species for planting in Xi'an city because of their better winter survival.

During the same period, the monthly rainfall, the relative air humidity and sunshine duration decreased. The number of sunny days has been reduced because of the increased particles in the air (Che Huizheng 2005). In 2011, the average daily air particulate matter (0.118 mg/Nm^3) of urban areas exceeded the standard by 18% (ADB 2003). The average air pollution data of SO_2 (0.042 mg/Nm^3) and NO_2 (0.041 mg/Nm^3) stayed at the upper limits of the national air quality standards. Moreover, water pollution has become severe in many rivers. Aquatic habitats in many rivers have been disturbed by the discharge of sewage, solid waste and other pollutants (ADB 2003). For example, Ba River and Chan River have been heavily polluted by drainage of chemical materials from domestic industry. Although the acute and chronic exposure to pollutants can kill off vegetation, death of vegetation induced by environment pollution (e.g. air pollution and water pollution) is rare in Xi'an city (Ouyang 2016; Xu et al. 2013; Yang 2007). However, the potential injury of trees by pollutants can be found in many cases, including for example reduced photosynthesis due to blocked stomata of leaves caused by air pollutants such as dust in the air (Ouyang 2016; Yang 2007). This kind of injury will obviously decrease plant growth.

As described in Chapter 2, vegetation, and especially trees, can be significant sources of cool air in summer, as well as active absorbers of air pollutants. Due to their large areas of vegetation and trees, urban green spaces, and especially parks, can be used to mitigate the environmental deterioration caused by urbanization. Furthermore, urban green spaces provide recreation opportunities, and thus enhance the environmental quality and human well-being. In recent years, the government has realized the severe urban problems and tried to implement a number of national and municipal measures to contain and control the urban heat island effect and rampant air pollution. Considering the continued fast urbanization and population growth in the study area, long-term approaches should focus on introducing well-developed multi-functionality to green spaces, providing especially regulating and recreational functions.

3.2 Methods

3.2.1 Outline of Methods

The main aim of this chapter is to outline the methodology used in this research. Taking Xi'an city as a case study, the methodology was applied to 22 public urban parks.

In general, the procedure of the approach is as outlined in Figure 3.2.

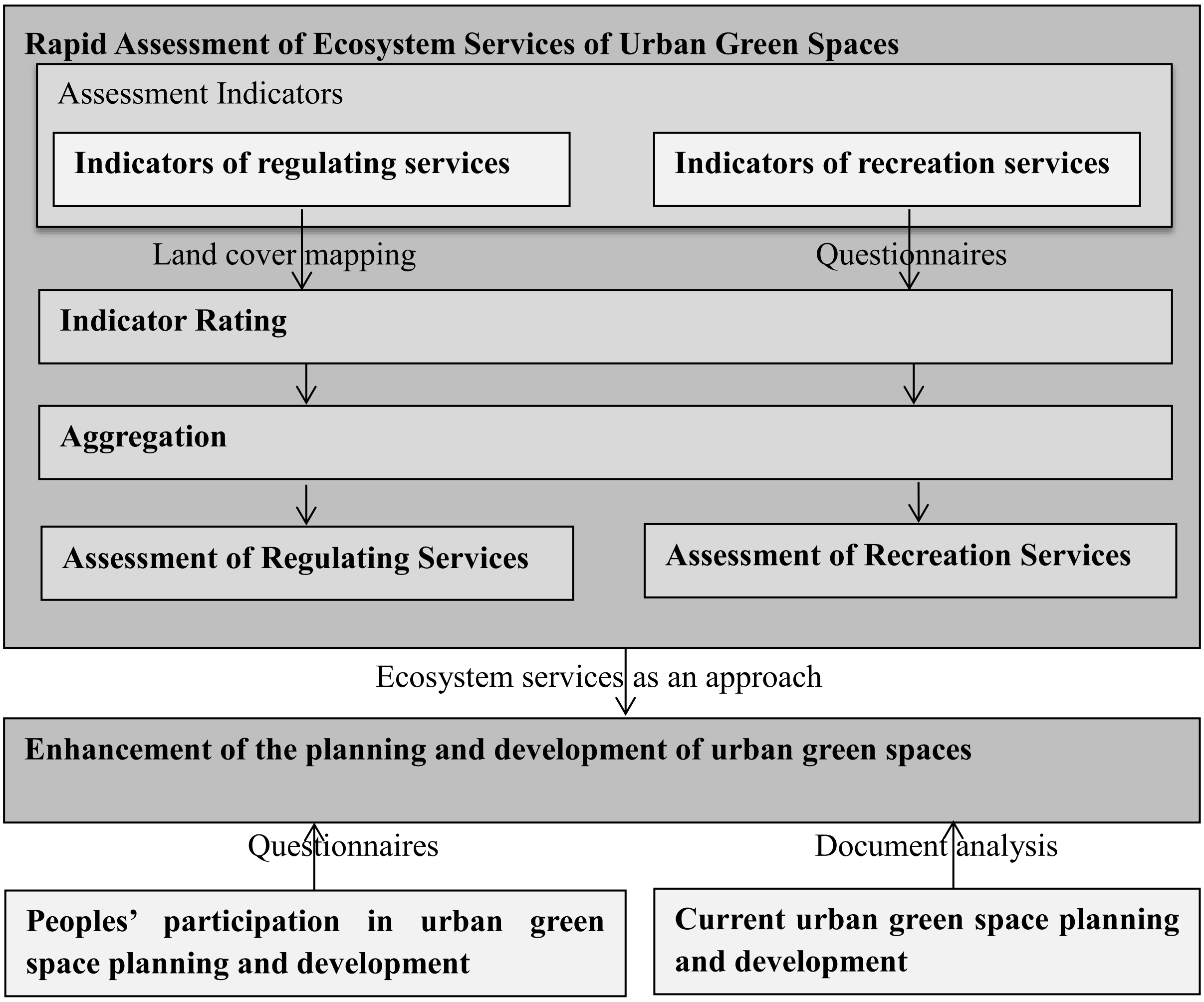

Figure 3.2 Procedure for applying the methods of this research

As Figure 3.2 shows, the methods of this research aimed to enhance urban green space planning and development according to assessments of indicators and citizens' attitudes towards green space ecosystem services, as well as the analysis of government documents concerning green space planning and development.

The rapid assessment of ecosystem services attempts to assess the regulating and recreational services of green spaces in Xi'an. Theoretically, this approach consists of indicators, indicator ratings and aggregations. All the information in the indicators was derived from a field survey, Google Earth (GE) images and a questionnaire survey. The indicators of the provision of regulating services were determined using land cover mapping, based especially on the vegetation structure types. The indicators of recreational services were determined by users' direct assessments collected via a questionnaire. In addition to respondents' direct assessments of recreational services, their use habits, preferred recreation activities, perceptions and demands for green spaces were also used to invoke citizens' participation in green space planning and development.

Moreover, the documents used for the planning and development of green spaces in Xi'an city were analyzed in order to identify insufficiencies of current green spaces. Subsequently, ecosystem services, questionnaires and document analysis were used as approaches to assess and enhance the urban green spaces of Xi'an.

3.2.2 A Rapid Ecosystem Service Assessment Approach

3.2.2.1 Summary of the Approach

In general, the rapid ecosystem service assessment method encompasses composite indicators, indicator ratings and aggregations (see Tables 3.2 and 3.3). The catalogue of composite indicators and indicator rating rules is based on a review of the relevant scientific literature (see Sections 2.2, 2.3 and 2.4). For ease of operation and comparison, the indicators should be kept simple and in a format that can be quantified.

In some studies, the indicators were weighted according to their importance. For instance, importance may be decided based on preferences derived from questionnaires (e.g. Curtis, 2004 and Gu et al., 2010). Other studies have attempted to evaluate ecosystem services without weighting indicators, so that all indicators carry the same weight (e.g. Liu et al., 2002; Chen et al., 2009 and Stern, 2010). The approach applied here also considers all indicators to have the same weight. On the one hand, this approach relies not only on the assessments of citizens but also on assessments of land cover and vegetation structure. As such, it is unsuitable to allocate weights by considering the preferences of citizens only. On the other hand, many studies have demonstrated the fact that regulating- and cultural services are all very important services provided by green spaces (e.g. Bolund and Hunhammar, 1999 and Jim and Chen, 2009). To our best knowledge, no study has been conducted on the basis of some such services being of greater importance than others.

Owing to specific conditions such as local temperatures, varying measurements and complex vegetation structures, it would be very difficult to ascertain a precise relationship between indicators and the provision of corresponding ecosystem services (temperature regulation, air pollution abatement etc.). Hence, it is difficult to reveal the relationships between decreased air temperature / air pollutants and certain types of vegetation, such as street trees or groups of trees (e.g. Mao et al., 1993 and Jim et al., 2003), and to use this relationship elsewhere directly. However, in order to produce an evaluation, a linear variation trend between an indicator and its impact on ecosystem services can be approximated (see Table 3.3). The process by which to identify an indicator’s impact can be seen as the indicator rating. Aggregation rules are then created in order to combine all indicator impacts into a final assessment result. These rules should be kept as simple as possible and should obey logic (see Table 3.3).

In practice, for a selected green space, the assessment will be achieved through three stages (see Tables 3.2 and 3.3): (1) apply a catalogue of composite indicators to the green space, with collected data being used as the basis for the assessment; (2) assign to each indicator its corresponding class range and impact score, with the help of ArcGis 10.0 software (ESRI inc., USA); and (3) combine the indicators’ impact scores into the final assessment results of specific ecosystem services via aggregation rules.

3.2.2.2 Indicators used for Assessment

Indicators of Regulating Services

Land cover and vegetation structure are the basis of regulating service assessment (see Section 2.3). In many cases, the indicators related to the assessment of air temperature regulation and air pollution reduction generated by urban green spaces are connected with the land cover, especially vegetation. In reality, the regulating functions of microclimate and air quality regulation are connected with each other. Many air pollutants are temperature-sensitive and lower temperatures decrease air pollution, especially in summer (Cardelino and Chameides 1990) (see details in Section 2.3.2). As discussed in section 2.3.2, vegetation and water cover (1.1), multi-layered vegetation cover (1.2), tree cover (1.3) and mature tree cover (1.4) were used as indicators to assess microclimate regulation in this study. Based on these indicators, in conjunction with the cover by evergreen species (1.5), air pollution removal was assessed (see Table 3.2).

Indicators of Recreation Services

Questionnaires are proposed as a method by which to evaluate the ecosystem services of green spaces (see Section 2.4). In this study, the recreational services of urban parks were assessed directly by citizens (see section 2.4.2). Since the main recreation services of urban green spaces are focused on aesthetic enjoyment, exercise, rest and children’s play (Chiesura 2004; Tzoulas and James 2010b; Zhang et al. 2015), questions related to these items were posed as indicators (2.1-2.10) to assess recreational services. These indicators were: (1) scenic beauty (2.1); (2) sporting facilities: the number of sporting facilities (2.2), the location of sporting facilities (2.3) and the maintenance of sporting facilities (2.4); (3) rest: the number of resting facilities (2.5), the location of resting facilities (2.6) and the maintenance of resting facilities (2.7); (4) children’s play: the area of playgrounds (2.8), the location of playgrounds (2.9) and the maintenance of playgrounds (2.10) (see Table 3.2).

Table 3.2 List of indicators used for the assessment of ecosystem services

Catalogue of Indicators of the Provision of Ecosystem Services
- Regulating services of urban green spaces (indicators: 1.1-1.5)
- Recreation services of urban green spaces (indicators: 2.1-2.10)

Nr.	Indicators			Indicator description
1.1	Microclimate and air quality	Land cover	Cover of vegetation and water	Proportion of vegetation and water areas in relation to the total green space area of the site
1.2		Vegetation structure	Multi-layered vegetation cover	Proportion of vegetation with more than two layers in relation to the total vegetated area of the site
1.3			Tree cover	Proportion of area covered by tree crowns in relation to the total vegetated area of the site
1.4			Mature tree cover	Proportion of area covered by mature tree crowns (tree height ≥10 m) in relation to the total vegetated area of the site
1.5	Air quality		Evergreen species cover	Proportion of area covered by the crowns of evergreen species in relation to the total vegetated area of the site
2.1	Recreation	Questionnaire	Scenery	Percentage of respondents satisfied with scenery
2.2			Number of sporting facilities	Percentage of respondents satisfied with the number of sporting facilities
2.3			Location of sporting facilities	Percentage of respondents satisfied with the location of sporting facilities
2.4			Maintenance of sporting facilities	Percentage of respondents satisfied with the maintenance of sporting facilities
2.5			Number of resting facilities	Percentage of respondents satisfied with the number of resting facilities
2.6			Location of resting facilities	Percentage of respondents satisfied with the location of resting facilities
2.7			Maintenance of resting facilities (e.g. table or bench)	Percentage of respondents satisfied with the maintenance of resting facilities
2.8			Area of playgrounds	Percentage of respondents satisfied with the area of playgrounds
2.9			Location of playgrounds	Percentage of respondents satisfied with the location of playgrounds
2.10			Maintenance of playgrounds	Percentage of respondents satisfied with the maintenance of playgrounds

3.2.2.3 Indicator Rating

As can be seen from the theoretical sections (see Section 2.3), regulating services include positive relationships between indicators of air temperature / air pollution and the decrease of temperature and air pollutants. Although the relationship cannot be shown accurately without local measurements, it can be approximated in a rough and simple manner (see Table 3.3). The increased cover ratio of indicators (e.g. vegetation and water, multi-layered vegetation, trees, mature trees and evergreen species) raises the possibility of temperature decrease and air pollutant reduction in green spaces, and this effect becomes increasingly evident when the cover ratio increases (see Section 2.3). Based on these facts, the indicators of air temperature and air pollution were simply classified into four scales, by logical, gradual and equal intervals of their cover ratio (see Table 3.3): 0-25% (very small), 26-50% (small), 51-75% (medium) and 76-100% (large).

The indicators from the questionnaires (2.1-2.10) were judged by respondents. In order to assess the provision of recreation services, the respondents were asked to select their answers from “excellent’’, “good”, “fair”, “poor” and “unclear”. Among all answers, the total proportion of positive answers (“excellent’’ and “good”) were used as satisfaction assessments, which were then divided by the gradual and average intervals: 0-25% (very dissatisfied), 26-50% (dissatisfied), 51-75% (satisfied) and 76-100% (very satisfied) (see Table 3.3). Therefore, the higher the number of positive assessments, the higher the degree of satisfaction.

Upon ascertaining the indicators and indicator ratings, scores were allocated to denote indicator impacts in order to simplify the aggregation in the next step. For each indicator, one point was allocated for the class range of 0-25%, while two points and three points were allocated for 26-50% and 51-75%, respectively. Four points were allocated for 76-100% (see Table 3.3). In a word, indicators with higher proportions attained a higher score and represented a greater impact on regulating services and recreation services.

3.2.2.4 Aggregation

Aggregation represents the deduction of results from indicators and rating rules. In this study, it can be seen from the theoretical part (see Sections 2.3 and 2.4) that all the indicators have positive interactions with each other. Therefore, the full impact scores of specific ecosystem services can be inferred by summing up the impact scores of all referred indicators (1.1 - 1.4 / 1.1 - 1.5 / 2.1 - 2.10). Then, the final assessments can be divided into very low (1 - 4 points / 1 - 5 points / 1 - 10 points), low (5 - 8 points / 6 - 10 points / 11 - 20 points), medium (9 - 12 points / 11 - 15 points / 21 - 30 points) and high values (13 - 16 points / 16 - 20 points / 31 - 40 points) by averaging the total impact scores (see Table 3.3).

Table 3.3 Approach for the rapid assessment of ecosystem services

Catalogue of Indicators used to Assess the Provision of Ecosystem Services			Rating			Aggregations		
Nr.	Indicators		Class range	Class description	Impact score	Total impact score		Assessment
1.1	Microclimate and air quality	Cover of vegetation and water	0-25%	Very small	1	1 - 4	1 - 5	Very low
1.2		Multi-layered vegetation	26-50%	Small	2	5 - 8	6 - 10	Low
1.3		Tree cover	51-75%	Medium	3	9 - 12	11 - 15	Medium
1.4		Mature tree cover	76-100%	Large	4	13 - 16	16 - 20	High
1.5	Air quality	Evergreen species cover						
2.1	Recreation	Scenery satisfaction	0-25%	Very dissatisfied	1	1 - 10		Very low
2.2		Satisfaction with the number of sporting facilities	26-50%	Dissatisfied	2	11 - 20		Low
			51-75%	Satisfied	3	21 - 30		Medium
2.3		Satisfaction with the location of sporting facilities	76-100%	Very satisfied	4	31 - 40		High
2.4		Satisfaction with the maintenance of sporting facilities						
2.5		Satisfaction with the number of resting facilities						
2.6		Satisfaction with the location of resting facilities						
2.7		Satisfaction with the maintenance of resting facilities (e.g. tables or benches)						
2.8		Satisfaction with playground area						
2.9		Satisfaction with the location of playgrounds						
2.10		Satisfaction with the maintenance of playgrounds						

In practice, the assessment of ecosystem services can be inferred by (1) implementing the indicators, their rating scales and scores; (2) averaging the total indicators' scores into four ranges, to which four values are assigned; and (3) summing the indicators' scores and then assigning them to their corresponding ranges and values (see Table 3.3). For example, if there is a park with 72% of water and vegetation cover, 65.5% of multi-layered vegetation, 30.3% of tree cover, 41.2% of mature tree cover and 32.2% of evergreen species cover, the park would get a score of twelve. The total scales of regulating services resulted in 20 points. By averaging, very low values ranged from 1 to 5 points, low values ranged from 6 to 10 points, medium ranged from 11 to 15 points, and high values ranged from 16 to 20 points. Thus, this park would be considered as having medium value in terms of regulating services.

3.2.3 Land Cover Mapping

In this study, the method of land cover mapping was used to collect and compute the information of the indicators of regulating services as aforementioned, including cover of vegetation and water, multi-layered vegetation, tree cover, mature tree cover and evergreen species cover.

3.2.3.1 Data Collection

The indicators of regulating services are related to land cover and vegetation structure of the study areas (22 urban parks), which were classified via observations in field surveys and interpretation of Google Earth (GE) images. Similar approaches were employed by Young et al., 2001; the URGE project, 2004, and Nicole Stern, 2010.

Generally, the main tasks of field surveys were to distinguish the types of land cover and vegetation structure, rather than to determine the boundaries of different land cover types. It is notable that there is no standard approach to image interpretation, although visual interpretation was preferred in this case. During the on-site-confirmation process, boundary illegibility (always induced by tree crowns) was unavoidable. However, small disparities do not appear to significantly impact the land cover proportions or the provision of ecosystem services by adjacent patches. For instance, Tratalos et al. (2007) ignored illegible patch areas of less than 10 m^2 because they considered that small areas of sealed surfaces (e.g. paths through parks or narrow roads) did not represent a barrier for the dispersal of most plant and animal species (Tratalos et al. 2007). Similarly, in this study, boundary illegibility of land cover areas smaller than 10 m^2 was not indicated, and any unclear boundaries connected with vegetation were counted as vegetation for the sake of consistency.

Prior to the field survey, additional survey sheets of land cover and vegetation structure were generated based on the literature review presented in section 2.3 (see Appendices 2 and 3). Site maps and printed GE images of the urban parks (image source: Google Earth 6.1) were prepared to aid the classification and boundary identification. Moreover, in cases where a type of land cover or vegetation structure was not listed on the survey sheet, the type was named and recorded in the supplementary column in Appendices 3 and 4.

Especially, possible classifications of vegetation height were defined for local contexts in this study. According to the consensus of landscape architecture in China and definitions taken from the book *Dendrology for Landscape Architecture* (Chen 1990), trees are defined as woody plants with a main stem taller than 5 m. Shrubs are defined as woody plants with no obvious main stem, normally below 5 m in height (Chen 1990). Considering the height variability of vegetation (e.g. Hercock, 1997 and Tzoulas and James, 2010), the height variations of vegetation in urban green spaces of Xi'an city can be classified into: (1) herbs; the herb layer is mainly composed of mown lawns (< 10 cm), flowers (< 20 cm, 20 - 50 cm or 50 - 100 cm) and bamboos (< 2 m); (2) shrubs, defined as all woody vegetation with a height below 5 m, except trees; (3) low trees: trees with a height of 5 - 10 m; and (4) mature trees or high trees: trees with a height greater than 10 m (see Figure 3.3).

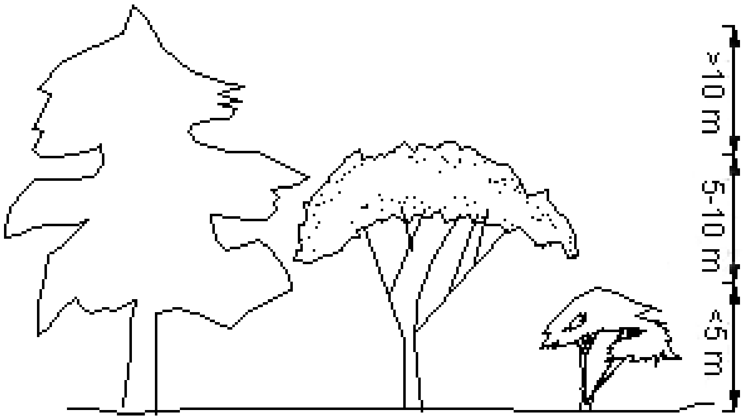

Figure 3.3 Height variations of woody plants (author's own drawing)

First Field Survey

In this study, field surveys were conducted both at the city level and the park level. The first field survey as a pre-test of land cover and vegetation structure types was conducted during June 2010. This pre-test aimed to modify the survey sheets for implementation of the second field survey. Based on government documents (Table 3.6), the 22 urban parks' area, location, history and characteristics were reviewed. Then, after the observation of said 22 parks, which was carried out by visits on foot and by car, six public parks including Lian Hu Park, Yong Yang Park, Feng Qing Park, City Sports Park, Xing Qing Park and Qu Jiang Yi Zhi Park were selected for testing (see Figure 3.1 and Appendix 1). Finally, some 172.51 ha of park area were investigated, which accounted for over fifty percent of the total area.

The steps undertaken during the first field survey at each of the six parks were:

(1) Preparation - proposing the possible land cover types

Beforehand, the locations of the park boundaries were drawn on the corresponding printed GE images. After on-site-confirmation, these were modified to improve accuracy. All patches within each park were numbered and identified in terms of their land cover types using survey sheet 1 (see Appendix 2), with the aid of GE images and park site maps. Provisional patch boundaries were drawn onto the printed GE images.

(2) Direct visual observation - determining the land cover and vegetation structure types. During the field survey at each park, land cover and vegetation structures were adjusted to local situations and recorded.

Firstly, the land cover types were determined. The land cover types and boundaries were confirmed on-site and modified at each patch. In this step, the point was to discern the vegetation and water areas from the other land cover types such as pavements, buildings and playgrounds (see Appendix 2). All the existing land cover types have been marked in the survey sheet 1 (see Appendix 2). If there were land cover types which did not conform to any of the given types, they were recorded as supplementary types (see Appendix 2).

Then, the types of vegetation structure were determined. Within vegetated patches, the information regarding vegetation structures including vegetation layers and vegetation compositions was visually estimated and recorded on survey sheet 2 (see Appendix 3). Vegetation layers were counted as one, two, three and multilayers (more than three layers). The different types of vegetation and their compositions were based on the presence of trees, shrubs and herbs, such as multi-layered trees over shrubs and lawns, groups of trees and groups of shrubs over lawns. Generally, vegetation types were classified by their appearance, physiological features and height range, i.e. the herbs were usually 10-20 cm, shrubs were always less than 5 m and trees were 5-10 m high (see Appendix 3 and the Section 3.2.3.1).

(3) Information supplementation

During the process of investigation, photographs were taken to show the patch appearance, land cover and vegetation structure.

According to the demonstration of the first field survey, the direct visual obseration method worked well in the local context of Xi'an city. Types of land cover and vegetation structure were categorized as shown in Table 3.4, which can be seen as providing classifications of the land cover and vegetation structure of green spaces in Xi'an city. Based on this table, the revised survey sheet 3 (see Appendix 3) was used in the formal field survey, i.e. the second field survey.

Table 3.4 Land cover and vegetation structure types within urban parks of Xi'an city

Land cover types	Sub-types	
Vegetation	Trees	Evergreen coniferous woodland Evergreen broadleaf woodland Deciduous broadleaf woodland
	Shrubs	Evergreen coniferous shrubs Evergreen broadleaf shrubs Deciduous broadleaf shrubs
	Lawns Flower beds Water plants Bamboo Trees covering shrubs Trees covering lawns Shrubs covering lawns Trees covering shrubs and lawns Multi-layered trees covering shrubs and lawns	
Pavements with scattered vegetation		
Pavements		
Playgrounds		
Buildings	Business buildings Garden architecture	
Water bodies	Lakes Fountains	

Second Field Survey

The second field survey was conducted in all of the 22 chosen public urban parks in Xi'an city (including the six parks included in the first field survey) during July and August of 2010.

The survey procedures were:
(1) Preparation - proposing the possible land cover types

Within each park, the preparations were repeated as in the first step of the first field survey, while all provisional patches were identified using the adapted types of land cover (see Table 3.4).

(2) Direct visual observation - determining all the information concerning land cover

and vegetation structure. The information on each patch was recorded using survey sheet 3 (see Appendix 4).

(i) Determining the cover of vegetation and water
In this step, the point was to differentiate with certainty the ground coverage of vegetation and water areas from the other five types such as pavements, buildings and playgrounds (see Table 3.4). All the numbered provisional patches were confirmed on-site, modified, and finally recorded in the second column of survey sheet 3 (see Appendix 4). The patch boundaries were also confirmed on-site and drawn on the GE images.

Subsequently, the steps focusing on the vegetation patches included:
(ii) Determining multi-layered vegetation
Vegetation layers were counted as one, two, three and multilayer (more than three layers); the different types of vegetation and their compositions based on trees, shrubs and herbs were recorded in survey sheet 3, using table 3.4. All the data were recorded in the third column of survey sheet 3. Then, the percentage of multilayered vegetation was estimated and recorded in the corresponding columns (see Appendix 4).

(iii) Determining the coverage with trees and mature trees
The percentage of trees and mature trees in each vegetation patch was estimated by walking around the patch ground, and recorded using gross intervals of 0-25%, 26-50%, 51-75% and 76-100% (see Appendix 4).

(iv) Determining the coverage with evergreens
Similarly, at each vegetation patch, the proportion of evergreen trees and shrubs was estimated and recorded using the same gross intervals of 0-25%, 26-50%, 51-75% and 76-100% (see Appendix 4).

As a supplement, the percentages of deciduous trees and shrubs, lawns and other types of herbs at each patch were estimated at the same time.

3.2.3.2 Data Processing and Analysis

Subsequent to the data collection, land cover maps of the 22 urban parks were drawn up and digitized using ArcGis10.0 (ESRI Inc., USA) using the following procedures:

(1) Using the software GetScreen1.1.1.0, GE images of the 22 parks were downloaded from Google Earth 6.1 (Google Inc., USA). The GE images were acquired on cloudless summer days before 2010, and were the same ones that were used in the field survey in order to determine the land cover and vegetation structure types;

(2) Geo-referencing the GE images of the 22 parks individually in ArcMap10.0 (ESRI Inc., USA) using the coordinates WGS_1984_UTM_Zone_49S;

(3) Establishing a new shape file (.shp) for each park in ArcCatalog 10.0 (ESRI Inc., USA) using the same coordinates as in the geo-referenced images;

(4) Tracing the figure of land cover and vegetation structure on the shape layer of each park based on the geo-referenced images, with the help of prepared drafts on the printed GE images;

(5) Input of the textual information related to land cover and vegetation structure into the attribute tables in each park's shape file, in order to allow surface classifications, map generation and relevant data output;

(6) Filling in the common types of land cover and vegetation structure with the same colors and inserting a north arrow, scale and legend on the shape layer, and finally outputting the digitized maps.

Using the shape files of the parks, the area of each patch was automatically generated by ArcMap10.0 (ESRI Inc., USA), after the digitized land cover mapping was completed. Thereafter, the percentage of each type of land cover and vegetation structure was quantified, and thus could be used for indicator ratings in the assessment of regulating services.

3.2.4 Questionnaires

A questionnaire survey was conducted within urban parks for the purpose of collecting data from persons who were asked randomly to take part; this approach was chosen due to the non-accessibility of mailing addresses, telephone numbers and household visits. Questionnaires permit closer interaction between researchers and research participants. The method provides a way in which to ascertain how well an individual's needs and desires are supported by their environment, and requires a relatively short time to cover a broad range of populations with different socio-economic backgrounds (Bell et al. 2004).

3.2.4.1 Sample Size of the Questionnaire Survey

While it is known that the sample size can affect the representativeness of results obtained by way of a questionnaire (Kornblum 2001), there is no agreement on the optimal size of a sample in the literature. A sample size of 500-800 people has been suggested as adequate from a statistical perspective (Kornblum 2001). However, in practice, deciding on a sample size typically depends on multiple factors, such as financial funding and time. The sample sizes of many questionnaires investigating the ecosystem services of urban green spaces were less than 500 people. For example, the number of interviewees was in the range of 200-350 participants in the research of Sanesi et al., 2006; Jim et al., 2006; Arnberger and Eder, 2011; Gerhardt, 2010 and Neuvonen et al., 2006.

In this study, a random sample of 500 questionnaires was conducted during two workdays and two weekends between June and August 2012 and May and June 2013, between 7:00 am and 7:00 pm. The sites investigated were the 22 parks in Xi'an city (see Table 3.5). The number of questionnaires to be completed was decided upon by the area of each park, with larger parks eliciting a greater number of completed questionnaires than smaller parks. Each questionnaire respondent was selected randomly by picking one out of three visitors encountered by the surveyor in sequence. Children below 15 years of age were excluded due to their limited ability to understand the questions. Moreover, considering the limited knowledge of some respondents, the survey attempted to make all questions easily understandable by typical citizens of Xi'an city; this was achieved by discarding specialized terms and engaging in oral communication or complementary explanations. The respondents completed the questionnaire independently, and only when assistance was requested did the interviewers provide further explanations.

Table 3.5 Questionnaire samples at the 22 selected urban parks

Research area	Recorded area (ha)	Total questionnaires	Completed questionnaires
Tu Men Road Park	2.81	10	8
Children's Park	3.00	10	9
Fang Zhi Park	3.70	10	9
Ci En Si Yi Zhi Park	4.50	10	7
Xi Qu Da Guan Yuan Park	4.20	10	10
Min Su Park	5.21	15	14
Xin Ji Yuan Park	6.00	15	13
Mu Ta Si Park	6.78	15	12
Mu Dan Yuan Park	6.98	15	14
Lian Hu Park	7.15	15	13
Wen Jing Park	7.60	15	14
Lao Dong Park	7.70	15	15
Ge Ming Park	10.4	20	16
Huan Cheng Xi Yuan Park	10.3	20	18
Yong Yang Park	12.00	20	17
Chang Le Park	19.60	25	19
Feng Qing Park	21.10	30	24
Qu Jiang Tang City Wall Park	31.00	40	34
City Sports Park	35.40	40	33
Tang Yan Road Tang City Wall Park	44.4	50	43
Xing Qing Park	50.20	50	42
Qu Jiang Yi Zhi Park	53.00	50	44
Total	353.03	500	428

3.2.4.2 Question Design

Undoubtedly, a critical step in the process of administering questionnaires is to establish reasonable and effective questions and answers. The questionnaire used in this research was developed mainly based on Oguze, 2000, Payne et al., 2002, Chiesura, 2004, Jim and Chen, 2006, Sanesi and Chiarello, 2006, Shan, 2009, Qureshiei et al., 2010, Gurung et al., 2011, Lo and Jim, 2012 and Casado-Arzuaga et al., 2013. The main aims of this survey were to determine citizens' use habits and preferences, as well as their recreational activities and their perceptions and expectations of the ecosystem services of green spaces.

A duration of no more than 20 minutes to complete a questionnaire is recommended, in consideration of the patience of typical respondents (Lohr et al. 2004). Therefore, combining the aims of the questionnaire, the context of Chinese society, and the respondents' comprehension and patience, 11 closed questions with single choices were eventually decided upon (see Appendix 5).

Firstly, respondents' personal information, including gender, age group, family status and vocation, was elicited as these data would aid in the assessment of the existence of any patterns by variable socioeconomic groups (e.g. respondents' expectations of green spaces or their use preferences by different age groups, vocation or family status) (Garrod and Willis 1999 ; Tyrväinen 2001) (see Appendix 5). Apart from the personal information, each question allowed the respondents to script their own answers if the provided answers were not a good fit.

Secondly, respondents' use behaviors were explored by way of six questions relating to visit preferences and motivations, including preferred green space type, how much time is spent on the way to the green space, use frequency, time and duration of visits, and preferred recreational activities in green spaces (see Appendix 5). For use habits, the optional answer categories for time spent on the way to the green space were: less than 5 min; 5-15 min; 16-30 min and over 30 min. The available use frequencies of green spaces were: daily; several times per week; 1-3 times per month; monthly; several times per year and less. Answers in connection with visiting time varied between morning, afternoon and evening, and also between weekdays and weekends. Possible answers in relation to the duration of visits were: less than one hour; one to two hours; half a day and nearly a whole day. Moreover, two questions were designed with three options: "very often", "often" and "occasionally". One such question concerned the respondents' preferred type of green space while the other related to the time of their visits. Lastly, the questions of preferred recreational activities were designed with four options: "very important", "important", "not important" and "neither important nor unimportant". The offered recreational activities included both popular active and passive activities (see Section 2.4), such as sports, use of recreational facilities, relaxation, having fun with friends or playing with family and enjoying scenery, fresh air and cooling off in summer (e.g. Dunnett, 2002; Özgüner and Kendle, 2006; Tzoulas and James, 2010b and Grahn and Stigsdotter, 2010).

Five questions aimed to probe respondents' perceptions, assessments and demands of the ecosystem services of urban parks. In this section, two questions asked respondents to select an answer from the four options: "very important", "important", "not important" and "neither important nor unimportant". One question concerned the importance of green spaces within neighboring residences or work places and schools, big city parks and parks in the outskirts. The other question was related to the importance of 17 specific ecosystem services. As shown in the theoretical part (see Section 2.4), the ecosystem services of green spaces related to human well-being mainly include recreational services, microclimate regulation, air quality improvement, water infiltration and biodiversity conservation, mainly in the forms of shading, cooling in summer, fresh air, number of plants and animals, wildlife habitats, water-soil conservation, places for recreational activities, more contact with nature and social-neighbor interactions (see Appendix 5).

Two questions were designed with five options: "excellent", "good", "fair", "unclear" and "poor"; these enabled respondents to gauge the quality of urban green spaces in Xi'an city and to nominate which features they were most satisfied with. As shown in the theoretical part of this thesis, natural features (e.g. vegetation, water and wildlife), recreational facilities (e.g. sports, resting and comforts), environmental quality (e.g. quietness), aesthetics (e.g. scenic beauty), management (e.g. cleanliness), safety, and easy access were seen as the features that high-quality green spaces should have (see Section 2.4). Therefore, at city level, features such as the amount of green areas, ecological functions and management of green spaces were asked to be assessed. For specific green spaces, features such as microclimate, air quality, tree shade, scenic beauty, the number of resting facilities and the amount of vegetation were assessed (see Appendix 5).

An additional four options - "strongly need", "need", "do not care" and "do not need" - were chosen for respondents in order to express their expectations for green spaces, namely what the respondents would like to see improved, out of the given 12 items. As mentioned in the theoretical part (see Sections 2.3 and 2.4), green spaces moderate the local climate mainly through evaporative cooling, shading, wind speed control and thermal capacity (Akbari et al. 2001; Andrade and Vieira 2007; Volker Heidt 2008). Moreover, they purify the air via O_2 release by vegetation, especially trees, and by their trapping, absorption and degradation of air pollutants (Beckett et al. 1998; Paoletti et al. 2011). Attitudes towards shade, wind-protected sites and water bodies were, therefore, inquired to reveal respondents' demands for regulating services.

According to existing research (see Section 2.4), apart from the desire for the natural appearance of trees, flowers and water features (Yuen et al. 1999), and easy accessibility (Jim and Chen 2006b; Sanesi and Chiarello 2006), citizens' recreational requirements for urban green spaces are mainly focused on features such as peace, quiet, cleanliness (Jim and Chen 2006b; Tyrväinen et al. 2007; Yuen et al. 1999), children's playgrounds, athletic fields and shelters (Özgüner and Kendle 2006), as well as enough recreational facilities such as tables, benches and drinking water (Herzele and Wiedemann 2003; Oguz 2000). Therefore, in this study, a set of questions related to opportunities for contact with nature, flowers, quiet areas, sports and resting facilities, and children's play areas were asked to evaluate the citizens' recreational demands for urban green spaces.

3.2.4.3 Data Processing and Analysis

All the questionnaire data were compiled and inputted into Microsoft Excel XP Professional Edition 2010 (Microsoft Corporation, USA), in order to develop a research database. A series of statistical analyses was accomplished with the help of SPSS 19.0 (IBM Corporation, USA) and Microsoft Excel XP Professional Edition 2010. General results were produced by way of descriptive statistics. Respondents' personal information was analyzed using the Chi-squared test. The relationships between respondents' use behaviors / recreational activities / perceptions / assessments / demands of green spaces and the socioeconomic / park variables were analyzed using Student's *t*-test and single-factor analysis of variance (one-way ANOVA). Moreover, the results were also analyzed by significance analysis and correlation analysis in order to reveal relationships such as the ones between regulating services and recreation services or between specific ecosystem services and green space site characters.

3.2.5 Document analysis

Documents containing text and images that have been recorded without a researcher's intervention (Bowen 2009), such as agendas, manuals, maps, charts and various public records are found in libraries, newspaper archives, historical society offices, and organizational or institutional files.

Documents provide background information and historical insights which can help researchers understand the historical roots of specific issues and indicate the conditions that produced the phenomena under investigation. Documents also provide supplementary research data as a knowledge base and a means of discovering changes and developments.

In this study, in order to obtain a better understanding of urban green space planning and development in Xi'an and to help answer the research questions (especially the last two), documentation and literature on planning and development were collected and analyzed (see Table 3.6). At the city level, the documents included master plans and green space system plans (see Table 3.6). Since the study specifically looked at the 22 urban parks of Xi'an city, the documents at the park level mainly included park maps and master plans for the specific parks (see Table 3.6). The review of documents concentrated on extracting the main objectives and strategies for building green space systems and specific green spaces such as urban parks.

At the same time, literature focused on green space planning and development in Xi'an city both at the city level and park level, especially in the past ten years, were reviewed (see Table 3.6). The review of literature was conducted mainly in order to ascertain the development, achievements and status of the green space system and individual green spaces, especially urban parks.

Table 3.6 Government documents on urban green spaces in Xi'an city

	Document	Remarks	Key literature
City level	Master plan of Xi'an city (1953-1972) Master plan of Xi'an city (1980-2000) Master plan of Xi'an city (1995-2010) Master plan of Xi'an city (2008-2020) Urban green space system plan of Xi'an (1995-2010) Urban green space system plan of Xi'an (2008-2020)	1). Before 1995, there was no special urban green system plan for Xi'an city. The master plans include paragraphs concerning green spaces; 2). The master plans include green space distribution maps and land use maps	Xueping Wu, 2012; Yu et al., 2006; Ting Wang, 2007; Bo Liu, 2007; Xiaoyan Zhao, 2007; Shuo Liu, 2013; Jing Feng, 2011; Hongxing He, 2010
Site (park) level	Park maps of the investigated 22 parks; Master plan of the investigated 22 parks		Yuan Li, 2014; Hang Shi, 2013; Dong Cui, 2011; Lei Wang, 2010; Ying Yan,2008; Qin et al., 2006; Shuo Liu, 2013; Jing Feng, 2011;

4 Planning and Development of Green Spaces in Xi'an

4.1 Overview of the planning documents

4.1.1 Emergence of a Green Space Structure Plan (1953-1972)

Before 1949, China experienced years of wars and social transformation. The Second World War and Civil War damaged the majority of urban greenery. During that time, the development of urban green spaces in Xi'an had nearly stagnated, even though the first modern park - Lian Hu Park, was built on the site of Qin Wang Garden in 1922. Up to 1949, only a few green spaces and palaces were preserved in Xi'an. Nevertheless, in subsequent years great changes were brought about.

With the establishment of the People's Republic of China in 1949, the modern Xi'an city was established. At that time, its area encompassed 131 km^2 with a population of one million. The city structure maintained the ancient chessboard shape and its grid of streets. By 1949, the majority of examples of ancient landscape architecture and green spaces in Xi'an had been destroyed in wars, notable exceptions being the Big Wild Goose Pagoda, the Small Wild Goose Pagoda a and Qin Wang Garden (XUPB 1980). The total greenery was reduced to 22 ha of green spaces and no more than 2500 street trees in Xi'an (XUPB 1980).

The development of the green space structure of Xi'an was initiated in 1953, but without specific and detailed discussions and planning maps (see Figure 4.1). The existing urban green spaces were protected and maintained by the local government. In the period of reconstruction, urban planning approaches were mainly influenced by the former Soviet Union, including the detailed planning norms and regulations, as well as urban planning and regional plans. The contents with regard to green spaces were arranged together with the planning of the road system, housing and squares. "Public urban green spaces" were put forward and underlined.

The 1953 version of the master plan with regard to green spaces focused on public parks. The plan suggested that parks at the city level should provide various recreational opportunities for the public, such as relaxation, sports, and meeting friends, as well as cultural, scientific and educational activities. The design of the parks were to consider different functional areas aiming at different groups of users, including playgrounds, quiet areas, sporting fields, outdoor theatres, clubs, and exhibitions with displays related to science and culture. Similar with the plan for municipal parks, it was suggested to distribute 24 district parks in high-density residential areas. In addition, 54 evenly distributed roadside green spaces were planned for the whole city. Specifically, children's parks were to be designed near municipal park or other suitable places.

Figure 4.1 Master plan of Xi’an city (1953-1972) (source: Xi'an Urban Planning Bureau)

4.1.2 The Green Space Structure Plan from the 1980s (1980-2000)

In 1978, the built-up area of Xi’an was enlarged to 162 km^2 with a population of 1.3 million (XUPB 1980), and the first urban green space plan was initiated (1980-2000). In this plan, the goal was for the total area of green spaces to reach 1100 ha by the year 2000, amounting to 10 m^2 per person.

The 1980 version of the master plan (1980-2000) announced the establishment of an easily accessible green space system encompassing municipal parks, district parks, roadside green spaces, attached green spaces and street trees (see Figure 4.2). It included planting of street trees and enlargement of pre-existing parks, as well as the development of new public parks, roadside green spaces, squares and attached green spaces. Street trees were connected to the road system and urban parks were to be linked by continuous stretches of the street-side trees.

The 1980 version of the master plan also proposed the concept of “green space system” and the principle of an interconnected green space structure. The main focus of urban green spaces was still on urban parks and the construction of parks for the protection of historical sites.

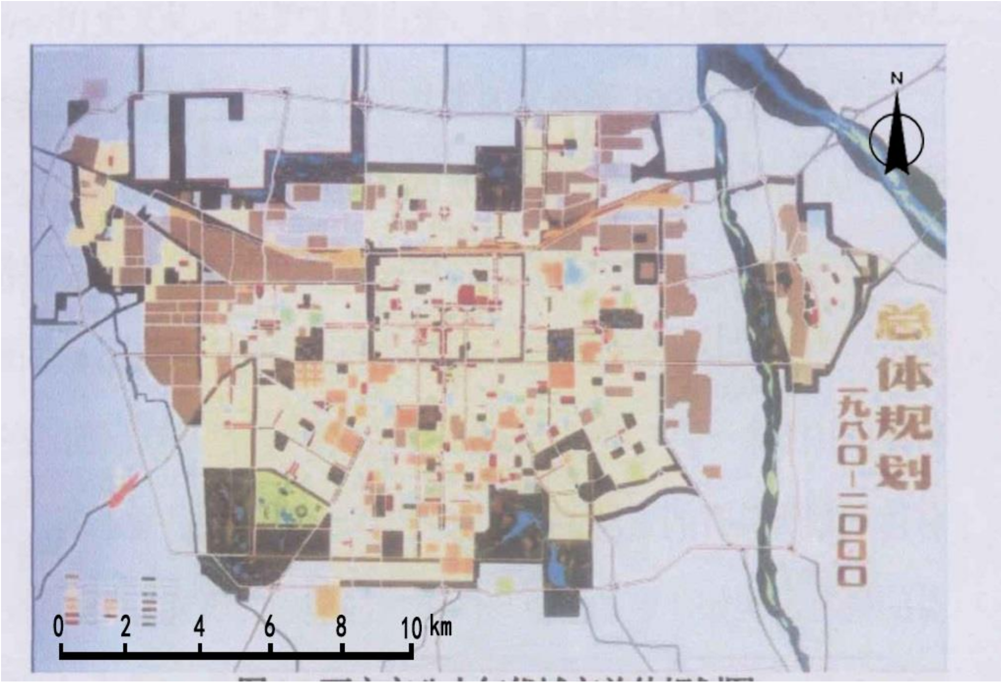

Figure 4.2 Master plan of Xi'an city (1980-2000) (source: Xi'an Urban Planning Bureau)

4.1.3 The Green Space Structure Plan from the 1990s (1995-2010)

Since the 1990s, Xi'an city has experienced an explosion of economic and urban development. The bulit-up area of Xi'an increased to 275 km^2 (XUPB 1995). The core of the city has expanded to areas between the Second and Third Ring Road. The budget for developing urban green spaces contiunued to grow and their development was promoted (see Figure 4.3). Bulding on demolished areas in the city was prohibited, and they were instead used for public green spaces. The main focus of urban greening was on developing urban parks and roadside greening. During this period, the urban planning law was issued and implemented by the goverment. The norms governing the definition and classification of urban green spaces and urban green space strucutre were published by the Construction Ministry of the P. R. China in 1993 (see Table 2.1 and 2.2).

The 1995 version of the master plan made the first "urban green space structure plan". It outlined the green space structure with more detailed informaiton, including the amount of vegetation cover, plant species and design approaches. It suggested that green spaces should form a network interconnected via linear green spaces, such as street trees (green belt), green buffers and waterside green spaces, to conncet the green patches such as public parks, attachted and residential green spaces and nurseries.

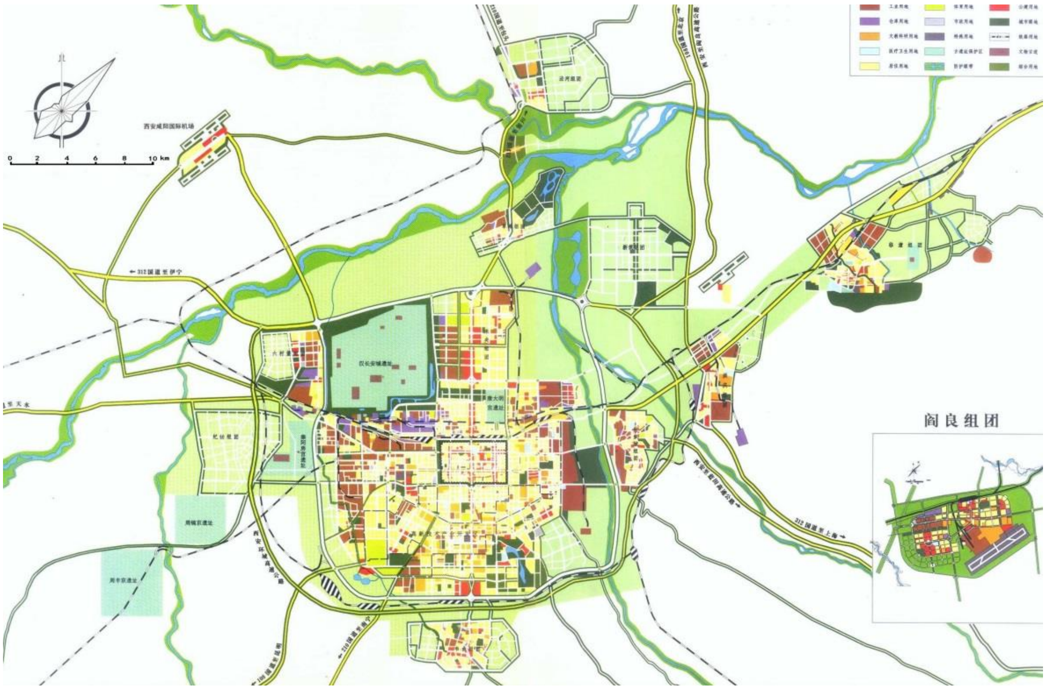

Figure 4.3 Master plan of Xi'an city (1995-2010) (source: Xi'an Urban Planning Bureau)

4.1.4 The Green Space Structure Plan from the 2000s (2008-2020)

By 2000, the built-up area had risen to 395 km^2 and the population living in the built-up urban area increased to 4 million (XUPB 2010). Since 2000, urban greening in Xi'an received special attention in the context of urban development because the city functions have evolved away from industry and agriculture, towards services. Moreover, urban planning development has changed its focus from the central zone of the city to the broader region (see Figure 4.4). The city started to develop "satellite towns" in order to alleviate land use pressures and urban sprawl.

The overall strategy for urban green spaces gradually emerged based on the goals of sustainable development and an ecologically sound environment, better living conditions and increased tourism. It linked ecology to concepts of protecting natural ecological resources, minimizing resource costs and damage, and constructing a balanced urban ecological environment. To enable truly sustainable development, a city should maintain clean air, water and environment, as well as a harmonious society. The ecological principles for urban green space planning include using waterside vegetation to help the restoration of rivers and wetlands, establishing green buffers to screen air pollutants emanating from the local industry, using street trees and other linear green spaces as green corridors for the movement of wild animals and plants, and exploring historical relics to promote the city's culture and public image.

At the same time, urban greening still focused on urban parks, residential green spaces, roadside green spaces and street trees. At the city scale, the aim was to create a system of various green patches interconnected with linear green spaces. At the regional scale, the green network would integrate green (vegetation), blue (wetlands and rivers) and mountain areas.

Figure 4.4 Master plan of Xi'an city (2008-2020) (source: Xi'an Urban Planning Bureau)

In this plan, the specific planning of green space size, plant choice and design was also addressed. It was proposed that all city dwellers should be able to reach neighborhood greenery within a distance of maximum 300 m. The district and municipal parks should be designed with maximum 500 m and 1000 m catchment areas, respectively. Plant configurations should show flower displays in spring, summer and autumn and keep a green appearance all year round. The rules suggested that flowers and evergreen species should be planted more. Specifically, the design of parks, attached green spaces, street trees, nurseries and green buffers was based on the green structure plan of 1995, emphasizing the strength of ecological services of green spaces. However, the government support for the achievement of green space plans was stressed due to economic factors and land use pressures.

4.1.5 Summary of the Green Space Plan

A review of the different versions of the urban green space plan for Xi'an shows that the plans have changed over time (see Table 4.1), and an overall planning concept and strategy for urban green spaces has been formed. The images of Xi'an city as a historical tourist city has been promoted. "Sustainable development" and natural resource preservation are the currently dominant discourses in planning. The plans for urban green spaces have moved from public green space development at a small scale towards green structure development at a larger scale.

The planning of green spaces for social benefit was paid great attention since the 1953 version of the plan, including recreational activities (in the 1953 version), citizens' living environment, local history and culture, aesthetics and city image (in the 1990 and 2000 versions). The suggested recreational activities mainly include relaxing, socializing, exercise and cultural / historical / education activities. The principle that parks should be divided into different areas for different recreation aims was emphasized. Also, the accessibility of green spaces was stressed in the 2000 version of the plan.

Table 4.1 History of the structure of green spaces in Xi'an

	Green spaces structure	Goals / principles of plan
Imperial period (11th century BC – 1912)	Private gardens, monasteries	Meeting the recreational and spiritual demands of royalty and the rich
Wartime period (1912-1949)	Private gardens, monasteries, and three public parks	Meeting the recreation demands of royalty and the rich; providing recreation to the general public
Early construction period (1949 – 1978)	Few public parks	Providing recreation opportunities for the public with a consideration of different use groups, such as relaxation, sports, meeting friends, or educational activities related to culture and science
Modern exploration period (1978 – 2008)	Public parks focusing on historical sites, street trees, roadside green spaces and attached green spaces	Forming a network of green space structures by connecting green patches via green belts
New century (2008 - 2020)	Public parks, attached green spaces, street trees, roadside green spaces, productive green spaces, green buffers etc.	Preserving and optimizing the ecological value of green spaces; achieving the sustainable development of urban areas and protection of natural resources;

The ecological benefits of green spaces have been increasingly stressed in the 1990 and 2000 versions of the plan. To preserve and optimize the ecological environment has become one of the most important goals of urban green space planning (the 2000 version of the plan). The green areas in the city gradually increased. Many mature trees present today in the city were planted during the period of the 1980s (Yan 2008).

The greening activities during the 1990s produced many of the green resources available today, such as street trees, green buffers and woodlands in parks (Yan 2008).

The 2000 plan explains the ecological perspective of urban green space planning. It aims to improve the environmental quality of the city and sustain the high-quality development of urban ecosystems, i.e. “ecological functions” at both the park and city level. An important improvement in the 2000 version of the plan is the proposition of ecological principles for urban green space planning. At the same time, the plan calls for the protection of natural ecological resources, the minimization of resource cost and damage, and the construction of a balanced urban ecological environment.

4.2 The Development of Urban Green Spaces in Practice

At the city level, the local government and administration play the most important roles in the overall process of urban green space planning, management and development. The main government organizations are the Planning Committee, Planning Bureau, Park Administration and Forestry Bureau. In the domain of private green spaces, an increasing number of institutions, enterprises and real-estate developers have expressed an interest in greening their own areas, and initiated the greening process. They are actors that directly influence the development of green spaces. Academics and experts are also involved in the planning and development process at both the city and local levels. Overall, the process of planning and development of urban green spaces involves the interaction of these actors, mainly within the public sector. However, other stakeholders and the public are far from having an influence on decision making.

During the past years, the City Government of Xi’an has increasingly invested in the development of urban green spaces (see Table 4.2). As shown in Table 4.2, the annual budget has increased over a dozen times within the last years. Especially after 2011, there has been a surge in the annual budget. At the city scale, the budget was allocated to different types of urban green spaces, with the vast majority of it being invested in the development of urban parks, squares and roadside greening. Urban parks account for over half of the investment (statistical year book of investment in Chinese cities 2010-2014). Accompanied with the increasing investment, the area of green spaces increased markedly, so that in 2010, the area of green spaces was 12140 ha, and four years later it had risen to 18914 ha (see Table 4.2).

At the city scale, an analysis of green space accessibility based on Landsat images of Xi’an city revealed that over half (52.22%) of the public green spaces can be reached by foot in thirty minutes, and all the public green spaces can be accessed by bus and automobile (Cui 2011). The accessibility of green spaces has therefore been guaranteed by a convenient traffic system.

Table 4.2 Annual budgets for urban green spaces in Xi'an over five years (Source: statistical year book of investment in Chinese cities 2010-2014)

	Year				
	2010	2011	2012	2013	2014
Number of municipal parks and specialized parks	66	68	72	81	85
Area of parks (ha)	1335	1478	1529	2406	2484
Area of green spaces (ha)	12140	13680	15196	17751	18914
Annual budget (thousand RMB)	6,306,280	2,106,180	17,800,000	12,800,000	18,196,520

In addition, the amount, distribution and characteristics of green spaces have been investigated by a number of researchers. The main observations can be summarized as follows: (1) There are fewer areas of green spaces within the second ring road than within the third ring road (see Figure 4.5 and 4.6); (2) Green spaces within the second ring road lack good connections due to the smaller amounts of roadside green spaces, street trees and green belts (Cui 2011); (3) The distribution of green spaces is uneven both within the urban and the regional area. The amount of green space in the southern area is significantly larger than in the northern area (Cui 2011; Shi 2013; Yan 2008; Yuan 2014). The main reason for this is the concentration of historical sites and natural resources in the southern area, due to which many parks were built especially in the south-east area of Xi'an city (Shi 2013; Wang 2007) (see Figure 4.4, 4.5 and 4.6). (4) A large area of green patches such as green buffers, woodlands and nurseries is concentrated in the suburbs and regional areas (Cui 2011). For example, woodlands are found only in very few larger parks, such as Xing Qing Park and Qu Jiang Yi Zhi Park. In the main urban areas, fragmented green patches (e.g. urban parks, residential and attached green spaces) and intermittent greening (e.g. street trees, squares and roadside green spaces) are the general formats of the green space system due to severe loss of greenery and intense land use pressures (Cui 2011; Shi 2013); (5) The green spaces such as residential and attached green spaces with smaller areas are usually composed of only a few plant species that are repeated many times. By contrast, the urban parks include greater numbers of species (Yan 2008; Yuan 2014); (6) Vegetation layers and compositions showed more configurations in urban parks than in other types of green spaces, especially than in roadside plantings and green buffers (Yuan 2014).

Figure 4.5 The regional development of the green space system of Xi'an city based on the plans from the 1980s, 1990s and 2000s (Source: Yuan, 2014).

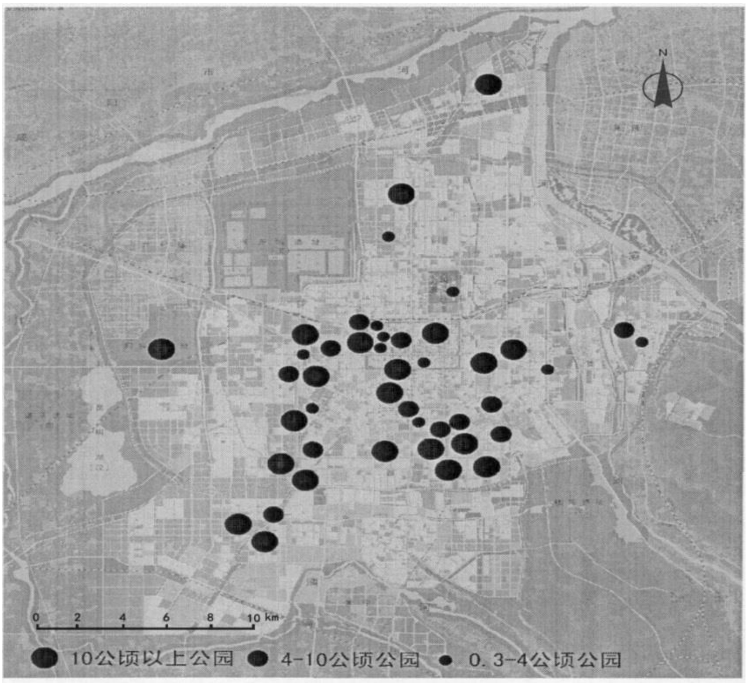

Figure 4.6 Locations of urban parks within the areas of Xi'an city inside the third ring road in the year 2009 (source: Wang, 2010)

The development of urban parks can be stratified by park age. There were only seven city parks in Xi'an before the 1980s. By 1990, the number of parks increased to 15, reaching an approximate total area of 311 ha (XUPB 1980). Since then, the city government has introduced stronger actions to develop public parks and squares. In the context of increased budgets and investment, as well as stronger city policy for improving the environment, at least one park has been constructed almost every year (Xi'an Statistic Year Book 1990-2010). The most obvious progress in the greening of Xi'an was made in the last two decades. By 2012, the number of parks increased to 55, with a total area of 1529 ha (Xi'an Statistic Year Book 2012), which was almost 4 times the number and 5 times the area from 1990.

The development of parks involves extensive preparation procedures and activities, including improving existing green spaces, reclaiming land from demolished old houses and expanding city borders. During the first stage of green space development (before 1980), urban green spaces including parks concentrated in the city core areas, i.e. inside the ancient city walls. The rebuilding of historical sites as public urban parks was the main greening activity, such as in Lian Hu Park and Xing Qing Park. Between 1980 and 2000, the greening activities focused on the areas within the second ring road. Urban parks were developed mainly around historic sites, such as in the case of Ci En Si Yi Zhi Park and Xi Qu Da Guan Yuan. After the year 2000, urban parks experienced sharp development in demolished areas and new district areas. Especially, the southern areas experienced increasing development, including wasteland reclamation and demolishing of buildings to expand the green spaces, which was done in large part following the establishment of the High-tech Zone and Qu Jiang District in the early 1990s (Shi 2013). Subsequently, the green spaces were extended to the areas between the Second and Third Ring Roads. Among the 22 parks investigated in this study, twelve were built between the years 2000 and 2009, including the majority of larger parks, such as Qu Jiang Tang City Wall Park, City Sports Park and Qu Jiang Yi Zhi Park. Most parks such as the City Sports Park, Wen Jing Park and Huan Cheng Xi Yuan were built on undeveloped land before the expansion of the city. By contrast, Qu Jiang Tang City Wall Park, Tang Yan Road Tang City Wall Park and Qu Jiang Yi Zhi Park were built around historic relics.

4.3 Challenges in the Planning of Urban Green Spaces

First and foremost, the goal regarding the per-capita amount of green spaces set in the master plans was not fulfilled. Despite the increasing amount of green spaces in Xi'an as such, the per-capita green area is still unsatisfactory due to the immense land use pressures and large population. In 2010, the green space area per person had risen to 5.16 m^2 (He 2010). Thus, the amount of green space per person is below the national standard of 7 m^2. The per-capita green space area in Xi'an is obviously lower than the 11.2 m^2 in Beijing and 12.5 m^2 in Shanghai, (data from the local Statistic Bureau website, Xi'an Statistical Yearbook 2012, http://tjj.xa.gov.cn/ptl/index.html), not to mention the green space area in highly developed countries (XUPB 2010).

Secondly, there is an obvious lag in the structural planning of urban green spaces (Hu and Duan 2004; Yan 2008). Moreover, the goals of urban green space planning regarding their functional provision were not always fully understood and implemented in practice. At project scale, the non-professional participants can understand and realize the recreation values of green spaces much more than their ecological values (Hu and Duan 2004; Yan 2008). The ecological functions of green spaces were considered in all versions of the plans. However, during the process of project construction, the plans with regard to ecological aspects of green spaces were sometimes changed for various reasons, including the shortage of ecological knowledge and insufficiencies of time, technical know-how and budget. During the design of urban green spaces, ecological considerations included increasing the vegetation cover at the expense of pavement, establishing multi-layered vegetation, planting more trees, increasing the number of plant species and using native species. Only the use of multi-layered vegetation and native species were followed through in some green spaces of Xi'an city (Chen and Zhang 2005; Shi 2013; Xu and Zhang 2006; Yan 2008).

Thirdly, comprehensive green space design and planning is still deficient. For instance, due to the limitations of natural greening recourses and inconsideration of the distribution of green spaces, the provision of green spaces is uneven among different areas, leading to unbalanced development in Xi'an (Hu and Duan 2004). As shown in figures 4.5 and 4.6, green spaces are mainly distributed in the south-west and south-east, especially in the areas between the second and third ring road. In fact, the total area of green spaces in the southern area of Xi'an is three times higher than in the north, and 10 times higher than in the west of the city (Shi 2013). This unbalanced distribution has made the southern area much more attractive for living and visiting (Shi 2013). Thus, how to promote the greening of northern areas and the whole city is a problem being discussed at the moment.

In addition, technical support has not kept pace with the improved understanding of ecology. In some cases, the planners wanted to introduce natural features such as natural river banks and wild plants in green spaces, but these designs were replaced by man-made features (Zhao et al. 2004). For example, the river banks and bottoms were lined with concrete rather than natural materials, primarily due to technical difficulties in managing the drainage and water levels (Zhao et al. 2004). Trees and shrubs were replaced by lawns due to budget constraints. However, while the cost of lawns seems lower at the beginning, the maintenance later on is normally expensive in terms of labor, tools and water (Zhao et al. 2004). The challenges thus mainly lie in the lack of investment in the early stages of green space development.

Furthermore, even though the planners knew the importance and value of urban green spaces at city scale, faced with intense land use pressures and economic benefits, it was difficult to control the land use of planned green spaces because there are no strict borderlines between the different space uses (Yuan 2014). Therefore, the space reserved for urban green spaces was occupied by commercial or other land use types in some cases. These non-green lands negatively influenced the connections of individual green spaces and hence their structural functions (Yuan 2014).

Generally, the main challenges facing urban green space planning are the implementation of ecological principles in specific greening projects, the balanced distribution and development of green spaces, sufficient investments and technical support, strict rules and laws for protecting and constructing green spaces, and the clarification of the responsibilities of individual government departments, especially regarding land use patterns and investment in urban green spaces.

5 Types of Land Cover and Vegetation Structures within Green Spaces of Xi'an

5.1 Land Cover Types within Urban Parks of Xi'an

According to the field investigation of 22 urban parks in Xi'an, six major land cover categories were present: (1) vegetation, (2) pavements with scattered vegetation, (3) pavements, (4) playgrounds, (5) buildings, and (6) water bodies (Table 5.1 and Annex 1).

As shown in Table 5.1, except for Qu Jiang Yi Zhi Park, the majority of parks were primarily covered with vegetation, with the percentage ranging from 43.5% to 85.9% (Table 5.1). Other categories included (in descending order in terms of area): pavements with scattered vegetation, water bodies, pavements, buildings, and playgrounds. The pavements were mainly present in the form of squares. The percentage area of pavements was significantly lower than that of vegetation, with the highest coverage being 29.7% and the lowest 2.0%. Furthermore, the area cover of buildings accounted for a very low percentage of the total area, ranging from 0.2% to 16.5% (Table 5.1). The majority of the buildings contained offices and businesses, such as restaurants, bars and shops. Elements of garden architecture that provide shading, rest and aesthetics were also found in over half of the parks, albeit at lower area percentages (Table 5.1).

The remaining three categories of land cover were not present within every park. Pavements with scattered vegetation were mainly squares covered with sparse vegetation such as trees, or trees covering shrubs. Xin Ji Yuan Park and Wen Jing Park had no pavements with scattered vegetation, while in the other 20 parks its percentage ranged from 0.1% to 27% of total area (Table 5.1). Water bodies in the parks of Xi'an city mainly included lakes and fountains. In the majority of parks, water surfaces were lakes. Min Su Park and Tang Yan Road Tang City Wall Park had no bodies of water. The remaining parks had water coverage ranging from 0.7% in Tu Men Road Park to 54.9% in Qu Jiang Yi Zhi Park (Table 5.1). Within the investigated 22 parks, the least represented type with the smallest percentage area of land cover was playgrounds. In fact, half of the parks had no specifically designated and designed playgrounds. In the parks having playgrounds, the percentage area ranged from a low of 1.1% in Lao Dong Park to a maximal 10.4% in Children's Park, Tu Men Road Park and Chang Le Park (Table 5.1).

Table 5.1 Percentages of different land cover types within the 22 investigated urban parks of Xi’an city

Land cover types \ Parks		Children's Park	Tu Men Road Park	Fang Zhi Park	Ci En Si Yi Zhi Park	Xi Qu Da Guan Yuan	Lian Hu Park	Min Su Park	Xin Ji Yuan Park	Wen Jing Park	Mu Ta Si Park	Mu Dan Yuan	Lao Dong Park	Ge Ming Park	Huan Cheng Xi Yuan	Yong Yang Park	Chang Le Park	Feng Qing Park	Qu Jiang Tang City Wall Park	City Sports Park	Tang Yan Road Tang City Wall Park	Xing Qing Park	Qu Jiang Yi Zhi Park
Vegetation		48.8	66.3	79.9	56.9	62.9	47.2	79.8	85.2	84.0	61.0	84.0	63.6	65.6	64.1	43.5	55.9	69.1	59.1	56.0	85.9	61.3	31.7
Pavements with scattered vegetation		14.2	15.8	8.8	20.1	27.0	12.2	3.3			9.2	2.7	12.5	14.0	2.8	24.8	17.9	1.0	3.7	18.0	0.1	3.1	3.4
Pavements		9.0	4.3	7.3	2.0	6.5	4.0	6.0	7.8	6.1	21.8	9.9	2.0	7.1	29.7	6.4	2.4	6.4	27.7	10.7	12.7	4.3	7.2
Playgrounds		10.4	10.4				7.9			4.3			1.1	5.8			10.4	3.4	4.1	1.2		7.3	
Buildings	Business buildings	14.7	2.2	0.6	15.8	1.8	0.7	0.2	0.2	2.1	0.2	0.4	8.2	1.7		10.4	4.1	0.4	0.9	5.8	1.3	3.8	0.4
	Garden architecture		0.4	0.9	0.7		0.1	10.7		0.3		1.3	2.3	0.9	2.4			4.7	0.6	0.3		0.8	2.4
Water bodies	Lakes	2.8	0.7	2.6	4.5	1.8	30.3		6.9	3.2	7.8	1.6	10.2	5.2	1.0	14.8	9.3	14.7	3.8	8.3		19.5	54.9
	Fountains																	0.4	0.2				
Total (ha)																							
Vegetation		1.03	1.85	2.74	2.51	2.80	2.24	4.80	5.15	5.25	3.85	5.84	4.66	5.08	7.02	4.89	9.59	15.56	18.89	18.94	34.84	30.02	16.05
Pavements with scattered vegetation		0.30	0.44	0.30	0.89	1.20	0.70	0.20	0	0	0.58	0.19	0.92	1.08	0.31	2.79	3.07	0.23	1.17	6.08	0.04	1.53	1.72
Pavements		0.19	0.12	0.25	0.09	0.29	0.23	0.36	0.47	0.38	1.38	0.69	0.15	0.55	3.26	0.72	0.41	1.43	8.86	3.61	5.17	2.11	3.65
Playgrounds		0.22	0.29	0	0	0	0.45	0	0	0.27	0	0	0.08	0.45	0	0	1.78	0.76	1.32	0.42	0	3.55	0
Buildings		0.31	0.07	0.06	0.74	0.07	0.04	0.65	0.01	0.16	0.01	0.12	0.77	0.19	0.26	1.17	0.71	1.15	0.46	1.98	0.52	2.23	1.43
Water bodies		0.06	0.02	0.09	0.20	0.08	1.59*	0	0.42	0.20	0.49	0.11	0.75	0.40	0.11	1.67	1.6	3.39	1.29	2.81	0	9.55	27.82
Area		2.11	2.79	3.44	4.43	4.44	5.25	6.01	6.05	6.25	6.31	6.95	7.33	7.75	10.96	11.24	17.16	22.52	31.99	33.84	40.57	48.99	50.67

* 0.47 ha of water plants were present within the 1.59 ha of water area in Lian Hu Park

Using the chi-squared test to analyze the relationships between land cover types and park characteristics, it was found that park age and location had significant relationships with the presence of playground features. In this study, a park's age was determined by the year it was built. The parks that were built before 1990 were termed older parks, and those built after 1990 were termed newer parks. Among the seven older parks, six had area percentages of playgrounds from 0-25%. By contrast, among the 15 newer parks, only five provided playgrounds at all (X^2 =5.238, P = 0.022) (Tables 3.1 and 5.1). While only three out of twelve parks that are located between the second and third ring roads had playgrounds, eight out of ten parks located within the second ring road had playgrounds. (X^2 = 6.600, P = 0.010) (Figure 3.1 and Table 5. 1).

5.2 Vegetation Structure Types in Urban Parks of Xi'an

Since the ecosystem services of green spaces are mainly generated by vegetation and influenced by its structure, knowing the variations of vegetation structure in parks is important for understanding their provision of ecosystem services. According to the field survey, there were a total of eleven different layers and compositions of vegetation structure within the 22 parks (Table 5.2 and Annex 1). These vegetation structure types were: (1) lawns, (2) flower beds, (3) water plants, (4) bamboos, (5) shrubs, (6) woodlands, (7) trees covering shrubs, (8) trees covering lawns, (9) shrubs covering lawns, (10) trees covering shrubs and lawns, and (11) multi-layered trees covering shrubs and lawns.

In all of the 22 urban parks, multi-layered trees covering shrubs and lawns accounted for the highest proportion of the total area among all the types of vegetation structure, followed by trees covering shrubs and lawns, deciduous broadleaf woodlands, and trees covering lawns (Table 5.3). All the parks had vegetation with three and more layers, with the coverage ranging from 16.2% to 80.1%, and reaching more than 50% in over half of the parks. Eight parks had trees covering lawns, and their percentage ranged from 2.9% to 20.2%. Nine parks had deciduous broadleaf woodlands, with area percentages ranging from 1.7% to 32.7%.

The proportion of evergreen coniferous woodlands, shrubs covering lawns and trees covering shrubs came next. Shrubs and lawns accounted for a lower proportion of coverage, while the proportion of bamboos, water plants, flower beds and evergreen broadleaf woodlands accounted for the lowest coverage. For example, seven parks had evergreen coniferous woodlands, with area percentages ranging from 0.6% to 15.8% (Table 5.3). Ten parks had lawns, and their percentage ranged from 0.8% to 6.5%, with a majority around 2.0% (Table 5.3). Flower beds, water plants, bamboos and shrubs were found in only a few parks, and with very low percentages of coverage (Table 5.3).

The chi-squared test showed that vegetation structures had significant relationships with park area and location. In this study, considering the variations of their total area, parks were divided into four groups: small area (0-5 ha), small to medium area (5-10 ha), medium area (10-30 ha), and large area (30-60 ha). There were lawns in all five parks with areas of 30-60 ha, while there were no lawns in any of the parks with areas of 10-30 ha (X^2 =11.110, P = 0.011) (Table 3.1 and 5.3). Considering the parks' locations, the majority of those located within the third ring road had lawns. By contrast, only one of the parks that had lawns was located within the second ring road (X^2 = 9.295, P = 0.002) (Figure 3.1 and Table 5.3). Trees covering shrubs were mainly found in parks with areas from 10-30 ha (X^2 = 8.192, P = 0.042), and only one small to medium (5-10 ha) and one large (30-60 ha) park contained the vegetation type of trees covering shrubs (Tables 3.1 and 5.3). In addition, seven parks had evergreen coniferous woodlands, six of which were located within the third ring road (X^2 = 4.023, P = 0.045) (Figure 3.1 and Table 5.3).

Table 5.2 Vegetation structures within urban parks of Xi'an city

Number of layers	Type	Sub-types
1	Lawns Flower beds Water plants (Reed/Lotus) Bamboos	
	Shrubs (including trimmed shrubs and hedges)	Evergreen coniferous shrubs Deciduous coniferous shrubs Evergreen broadleaf shrubs Deciduous broadleaf shrubs
	Woodlands	Evergreen coniferous woodlands Deciduous coniferous woodlands Evergreen broadleaf woodlands Deciduous broadleaf woodlands
2	Trees covering lawns Trees covering shrubs Shrubs covering lawns	
3	Trees covering shrubs and lawns	
>3	Multi-layered trees covering shrubs and lawns	

The majority of parks investigated in this study had three to six types of vegetation structure. Xing Qing Park contained the greatest number of types of vegetation structure (nine): evergreen coniferous woodlands (0.6%), lawns (1.4%), evergreen broadleaf woodlands (3.1%), flower beds (3.3%), trees covering shrubs (3.7%), trees covering lawns (4.8%), deciduous broadleaf woodlands (6.5%), multi-layered trees covering shrubs and lawns (12.2%), and trees covering shrubs and lawns (25.9%)

(Table 5.3). Xin Ji Yuan Park followed with eight types (Table 5.3). However, the majority of the parks (20) were covered by a lower variety of vegetation structures (less than seven types). These included Xi Qu Da Guan Yuan (six), Ci En Si Park (five), Chang Le Park (four) and Fang Zhi Park (three) (Table 5.3). Two parks had only two types of vegetation structure and three parks had only one (Table 5.3).

The smallest parks: Children's park and Tu Men Road Park only had multi-layered vegetation. Moreover, they had a relatively large cover of pavements with scattered vegetation, and the highest percentage coverage of playgrounds. Min Su Park also only contained multi-layered vegetation. Interestingly, having the largest percentage of garden architecture (10.7%) of all the investigated parks is another feature of Min Su Park.

Qu Jiang Yi Zhi Park had the largest coverage of lakes (54.9%). In addition to lakes, the park was mainly covered by lawns, and trees covering shrubs and lawns. Additionally, Lian Hu Park also had a large coverage with lakes (30.3%), though trees covering shrubs and lawns (37.4%) accounted for the largest percentage if its total area. Water plants (8.2%) were a prominent feature of Lian Hu Park. Wen Jing Park also had 0.2% of water plants. Moreover, Wen Jing Park had 9.1% of bamboos, 8% of evergreen coniferous woodlands, 0.2% of flowerbeds, and 3% of lawns. In spite of this diversity of vegetation types, the 63.6% of trees covering shrubs and lawns represented the overwhelming majority of surface cover in this park.

Extensive shrub cover was found in Yong Yang Park, Feng Qing Park and Tang Yan Road Tang City Wall Park (Table 5.3). Yong Yang Park had the largest percentage cover of pavements with scattered vegetation (24.8%), followed by 14.8% and 10.4% of water and buildings, respectively.

There were significant relationships between park characteristics and total number of types of land cover and vegetation structure, as determined using the chi-squared test. However, such relationships were not found between park characteristics and either the types of land cover or of vegetation structure. Among the seven older (< 1990s) parks, six had over eight types of land cover and vegetation structure, in comparison to nine out of the 15 newer parks ($X^2 = 19.695$, $P = 0.012$). The parks located within the second ring road were mostly older parks (Table 3.1 and Figure 3.1). When stratified by park age, park location showed a similar influence on the types of vegetation structures ($X^2 = 17.160$, $P = 0.028$).

Table 5.3 Percentages of different vegetation structures within the 22 studied urban parks of Xi'an city

Vegetation structures \ Parks	Children's Park	Tu Men Road Park	Fang Zhi Park	Ci En Si Yi Zhi Park	Xi Qu Da Guan Yuan	Lian Hu Park	Min Su Park	Xin Ji Yuan Park	Wen Jing Park	Mu Ta Si Park	Mu Dan Yuan	Lao Dong Park	Ge Ming Park	Huan Cheng Xi Yuan	Yong Yang Park	Chang Le Park	Feng Qing Park	Qu Jiang Tang City Wall Park	City Sports Park	Tang Yan Road Tang City Wall Park	Xing Qing Park	Qu Jiang Yi Zhi Park
Lawns			1.5	1.8	3.6			2.2	3.0									6.5	3.0	0.8	1.4	2.7
Flower beds									0.2							0.8					3.3	
Water plants						8.2			0.2													
Bamboos									9.1													
Shrubs															7.7		13.9			2.9		
Evergreen broadleaf woodlands																					3.1	
Evergreen coniferous woodlands				2.5	15.8		13.7	6.5	8.0						7.2						0.6	
Deciduous broadleaf woodlands					5.6			13.9			3.9	30.8	9.0	6.4			1.7			32.7	6.5	
Trees covering shrubs								4.1							6.1	14.3	11.9				3.7	
Trees covering lawns				2.9	9.9			10.7							3.7		5.1	17.7		20.2	4.8	
Shrubs covering lawns			12.2	3.8				11.1					1.0	7.0	2.6	5.9		4.8	2.5			
Trees covering shrubs and lawns					3.2	37.4	42.5	26.5	63.6			22.2	55.3	50.7	16.2		20.1	30.0	12.6	29.4	25.9	29.0
Multi-layered trees covering shrubs and lawns	48.8	66.3	66.2	45.8	24.8	1.6	23.7	10.3		61.0	80.1	10.6				34.9	16.4		37.9		12.2	

5.3 Discussion

5.3.1 Comparison of Land Cover / Vegetation Structure Types in Xi'an city with those Reported in Similar Studies

There were six types of land cover and eleven types of vegetation structure within the urban parks of Xi'an city (see Tables 5.1 and 5.2). Layers and compositions of vegetation structure varied from simple to relatively complex (see Table 5.3, Figure 5.1 and Annex 2). Perhaps unsurprisingly, vegetation accounted for the highest percentage of area in the majority of parks. Multi-layered trees covering shrubs and lawns, and trees covering shrubs and lawns were the dominant types of vegetation structure (see Table 5.3).

Considering the categories of land cover and vegetation, older parks showed relatively higher numbers of types of land cover and vegetation structures than newer parks. Green spaces in Xi'an city were built successively outward. Therefore, older parks in most cases are the parks located within the second ring road. The older parks had a long time to form the mature appearance of their vegetation, and therefore benefited from the maintenance of the multi-layered vegetation and compositions of different plant communities.

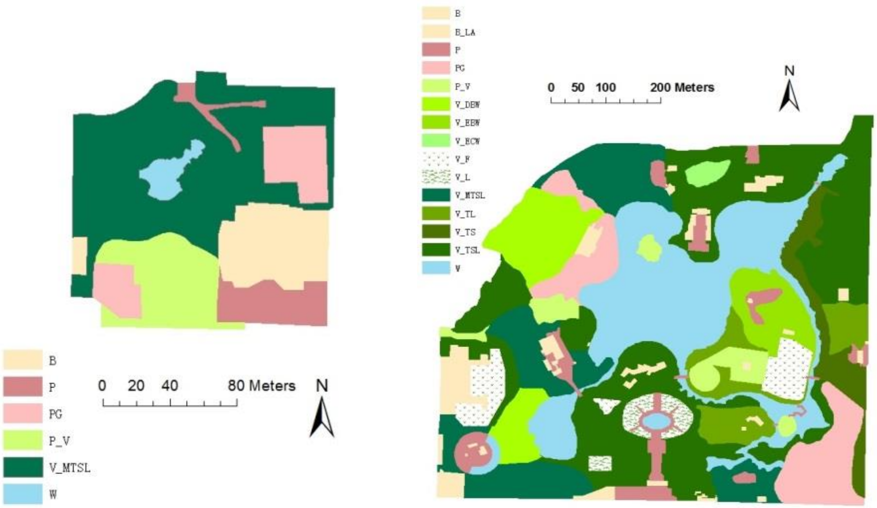

Figure 5.1 Comparison of land cover and vegetation structure between Children's Park (left) and Xing Qing Park (right)

By implementing a common classification, specific types of land cover and vegetation structure within urban green spaces can be compared. It is notable that open soils, ice houses, car parks, walls, rough grass, infested grass, pastures, hay meadows and agricultural crops were not found in the parks of Xi'an, in contrast to findings from studies in other countries (e.g. Pauleit and Duhme, 2000; Young and Jarvis, 2001; Cornelis and Hermy, 2004 and Gao et al., 2012). These results may be explained by the fact that in Chinese cities, as highly artificial urban ecosystems, urban green spaces usually lack natural elements and original types of vegetation. Pavements often replace open soils. Mowed lawns, shrubs and hedges have replaced naturally growing vegetation (e.g. rough grass, pastures and hay meadows). Agricultural crops and other economic plants were also not present due to the limited palette of plant species (Xu and Zhang 2006). The predominant design styles of parks obviously acted to limit variations in land cover and vegetation structures.

The percentage area of pavements in the urban parks of Xi'an was relatively higher than in the parks from studies by Pauleit and Duhme (2000) and Young and Jarvis (2001). For example, in parks in Munich, pavements accounted for 3% of the total area, while among the 22 investigated parks in Xi'an, ten had over 10% of their area in pavements, even reaching 29.7% in Huan Cheng Xi Yuan. The increased amount of sealed surfaces can change the ecological performance of parks in terms of decreasing the parks' impact on air temperature regulation because of reduced transpiration (Lhomme and Monteny 2000; Zhang et al. 2014). However, this relatively high proportion of pavements within green spaces can provide more space for holding public meetings, public events, and recreational activities, by being able to admit large numbers of citizens without damaging the vegetation.

In addition, the characteristics of vegetation in Xi'an differed in some areas from those described in other studies. For example, there were no large areas of lawns in the green spaces of Xi'an. In fact, the percentage area of lawns ranged from 0.8% to 6.5% (see Table 5.3). By comparison, lawns occupied around 80% of the total park areas in Munich (Pauleit and Duhme 2000), and grasslands accounted for almost 100% in some parks of Black Country in the UK (Young and Jarvis 2001). By contrast, the trees cover was found to be relatively low in these studies. For example, in the study conducted in Munich, the percentage of trees was 15% of the total area of the investigated parks (Pauleit and Duhme 2000), whereas in Xi'an, tree cover accounted for at least 26%, and in some cases for over half of the park area (see Figure 7.3). This lack of lawns may lead to a decrease of open scenery and limit some recreational activities. However, the higher coverage of trees is beneficial for the enhancement of regulating services, because trees (and especially mature trees) are considered the most important factor in decreasing air temperature and air pollution (Nowak 2002; Nowak and Dwyer 2007; Picot 2004). The emphasis on trees rather than lawns may reveal a focus on regulating services of green spaces in Xi'an city due to very tense land use pressures and limited areas of green spaces.

5.3.2 The Relationships between Land Cover / Vegetation Structure and Park Variables

The chi-squared test revealed that some types of land cover and vegetation structures were influenced by the variables of parks. For example, playgrounds had significant relationships with park age and location, while park location and area influenced the distribution of lawns.

In the 22 investigated parks, all of the five largest, with areas of 30-60 ha, had open lawns. However, the four medium parks with areas of 10-30 ha had no open lawns at all. Under the severe land use pressures in Xi'an, park designers evidently first considered the benefits which are connected with citizens' well-beings, such as regulating services, as has been stressed by the green space plans. Compositions of groups of trees and shrubs rather than open lawns possibly provide more regulating services because of their stronger transpiration, shading and absorption of air pollutants (see Section 2.3.2.2). Therefore, the vegetation structures with multiple layers and large canopies are considered more suitable for parks with limited area. As a result, the larger parks can therefore provide open lawns due to their sufficiently large areas.

However, compared to the small-sized parks, the shortage of open lawns in medium sized parks may be caused by the individual parks' features and design styles. Every park has its own compositions of land cover and vegetation structures, which makes it difficult to explain all the reasons for their creation. In the four medium-sized parks, multi-layered vegetation occupied the largest percentage of area. Additionally, two of them had over 10% of water surface cover, and three had over 20% of pavements and pavements with scattered vegetation (see Table 5.1). For example, Huan Cheng Xi Yuan had the largest percentage of pavements (29.7%). Yong Yang Park had the largest percentage of pavements with scattered vegetation (24.8%), in addition to its 14.8% of water surface, 7.7% of shrubs and 7.2% of broadleaf evergreen woodlands. Chang Le Park had the largest percentage of playgrounds (10.4%) and 17.9% of pavements with scattered vegetation. Feng Qing Park had 13.9% of shrubs and 14.7% of water surface (see Tables 5.3 and 5.1). Thus, since there are many other types of land cover and vegetation in a limited area, it is difficult to design special open lawns in such parks.

While having no lawns, the medium-sized parks (10-30 ha) usually had the vegetation structure of trees covering shrubs. These parks also had higher area percentages of impervious surfaces (see Table 5.1). The pavements in these parks replaced the lawns or grasses. Therefore, trees covering shrubs was a typical vegetation structure in this case. Generally, as discussed above, the medium-sized parks were usually characterized by trees covering shrubs, pavements, water bodies, and no lawns.

Considering the parks' locations, it was found that the majority of parks with lawns were located between the second and third ring roads, with only one lawn-containing park located inside the second ring road. The parks located inside the third ring road were always newer, and a part of them were large. Traditional design styles in Chinese parks are characterized by abundant vegetation layers, winding roads, and dedicated rock formations (Lou 2003). Moreover, the vegetation and buildings should set each other off (Lou 2003). Nowadays, park designers may try to present open scenery and playing fields via lawns in parks, as is traditional for western gardens.

In addition, seven parks had evergreen coniferous woodlands, six of which were located within the third ring road. Since the parks located inside the third ring road are usually the newer parks, this observation may indicate that, in recent years, park designers have started to realize the importance of evergreens (see Section 2.3.2.2). They therefore appear to have chosen more evergreen coniferous trees in order to meet the demand for regulating functions from the viewpoint of ecology, and to keep the parks green all year round from the viewpoint of aesthetics, as the green space plan suggested.

However, the older parks located within the second ring road are more likely to provide playgrounds. This is because the provision of recreational opportunities such as playgrounds in parks was one of the most important objectives in the pre-1990s versions of the master plan and green space plans in Xi'an (see Section 4.1). Therefore, under the direction of master plans from that period, park designers usually considered the provision of playgrounds. In later years, the focus on providing special playgrounds in parks was reduced due to the higher emphasis on ecological functions of parks and increased opportunities for entertainment in various other venues in the city.

In summary, the urban parks of Xi'an city have varied layers and compositions of land cover and vegetation, and are characterized by fewer lawns and more pavements than their western counterparts. The majority of the parks have large covers of vegetation with more than two layers, and great expanses of pavements. A continuous cover of flower beds, bamboos or water plants is rarely seen. Park age, area and location were the factors that influenced the types of land cover and vegetation structure within parks. Among the 22 investigated parks, older parks usually showed more variations of land cover and vegetation structure. The larger parks located within the third ring road all had lawns. However, special playgrounds can be found in the older parks located inside the second ring road. In addition, evergreen coniferous woodlands were frequently found in the parks that were located inside the third ring road, which are mostly newer. Although it is difficult to explain all the attributes of land cover and vegetation types in the parks, the main results can be explained by the prescriptions made in the master plans of green spaces during the time of each park's construction, in addition to the size and design style of the park in question.

To our best knowledge, this is the first study that attempts to investigate and classify the types of land cover and vegetation structure using a large number of public parks in Xi'an city. It compares the types of green spaces in Xi'an city with other studies, and explores the factors influencing the types of land cover and vegetation structure. Other studies focused on one or several green spaces (e.g. Qin et al., 2006), or on green space as a whole (e.g. Shi, 2013), but did not provide land cover maps including the vegetation information both in vertical and horizontal dimension, as is the case in this study. However, this study does not provide more detailed information, such as the exact plant species use, tree diameter at breast height, and shapes of different patches of surface cover within green spaces. More detailed information may therefore merit further investigation in the future.

6 Citizens' Use, Perceptions, Assessments and Demands for Green Spaces in Xi'an

6.1 Response Rate and Respondents' Characteristics

Of the 500 administered questionnaires, 428 were returned with complete answers. Among these, the numbers of male and female respondents were equal (Table 6.1). The ages of respondents were mainly between 26 and 65. The age group 26-45 accounted for 42.5%, followed by 46-65 (34.3%) and 15-25 (15.9%). The senior >65 group only occupied 7.2%. Over half of respondents (61.9%) had at least one child (aged 0-14). Couples and singles accounted for 29.2% and 8.9% of the sample, respectively. In addition, the majority of respondents (61.4%) were ordinary working people. Additionally, 11.7% were retirees and 10.7% were self-employment. Very limited proportions comprised students and unemployed persons.

Table 6.1 Respondents' personal information

Personal information	Category	Percentage of respondents	Percentage of census	Chi-squared test	*p*-value
Gender	Male	50.0	51.3	0.273	0.601
	Female	50.0	48.7		
Age	15-25	15.9	78.7	2.974	0.085
	26-45	42.5			
	46-65	34.3			
	>65	7.2	8.5		
Children	No	38.1	12.0	275.72	<0.001
	Yes	61.9	88.0		
Vocation	Student	9.4	22.9	108.31	<0.001
	Employed	61.4	61.9		
	Self-employed	10.7	5.4		
	Unemployed	6.8	4.0		
	Retiree	11.7	5.8		

Data source: Census from Xi'an Statistic Yearbook (2011)
Significant at 0.05 level

Socioeconomic profiles were compared with the 2011 population census (Xi'an Statistic Yearbook 2011). The chi-squared test showed that gender and age matched the census data well ($P > 0.05$). However, fertility status and vocation deviated from the census data ($P < 0.05$). Compared with the census, fewer respondents had children.

This result may be due to lower participation of visitors accompanied by children because they could not leave their children alone during the time needed to complete the questionnaire. The percentage of employed respondents was nearly equal to that in the census. Students were markedly less represented than in the census because students were defined in the census as all people from nurseries, primary schools, high schools and universities, while in this survey, the category only included those over 15 years old due to their ability to understand this type of questionnaire. More retirees than in the census may indicate that retirees have more spare time to go to parks and/or were more inclined to take part in the survey.

6.2 Citizens' Use Behaviors of Green Spaces

6.2.1 Use Types and Variations among Social Groups

Public parks were chosen as the most often used type of green spaces by residents in Xi'an. In fact, an overwhelming majority comprising 80.8% of the respondents stated that they most frequently used the public parks (Table 6.2). Residential green spaces (75.7%) and green spaces near schools or work places (21.3%) were their second and third choices. Roadside green spaces and squares were seldom chosen (11.0%). The analysis of statistical significance of the connection between often-used types of green spaces and socioeconomic variables showed that vocation had a significant relationship with the preference for roadside green spaces and squares ($p < 0.05$). More employed respondents (22.4%) were frequent users of roadside green spaces and squares than other groups, with the percentage ranging from 1.4% among students to 3.6% among the self-employed ($p < 0.05$). This may be due to the simple fact that employed respondents often pass through roadside green spaces or squares on their way to work. The other three socioeconomic factors had no statistically significant association with often-used types of green spaces ($p > 0.05$).

Table 6.2 Types of often-used green spaces (percentage)

Type of green space	Very often	Often	Occasionally
Public parks	80.8	17.3	1.9
Residential green spaces	75.7	22.7	1.6
Roadside green spaces and squares	11.0	48.6	40.4
Green spaces near work places or schools	21.3	43.0	35.7

6.2.2 Citizens' Use Frequencies, Times and Durations of Visits, and Variations among Social Groups

Over half of the respondents (54.0%) stated that they travelled 6-15 minutes to their often-used green spaces (Table 6.3). 22.0% and 20.0% of respondents usually spent no more than 5 minutes and 16-30 minutes on the road, respectively. Only a small minority of visitors (4.0%) needed more than 30 minutes' travel time. Regarding the frequency of visits to green spaces, 48.6% of respondents stated that they visited green spaces several times per week. The daily users accounted for 30.4%, followed by weekly (14.7%), 1-3 times per months (4.9%) and monthly users (1.4%). It can therefore be seen that the vast majority of respondents were active in using green spaces. However, the duration of a typical visit was not long, often involving a stay of one to two hours (52.1%) or less than on hour (30.1%). Only 15.7% and 2.1% stayed half a day or nearly one day, respectively. In addition, there was no big difference between the most frequent visits on weekdays (36.7%) and on weekends (43.7%), even if the visits were slightly more numerous on weekends than on weekdays. Moreover, visits by respondents from the "very often" category were typically conducted in the evening (42.5%) and morning (39.0%).

In order to simplify the analysis of the statistical relationsships with the attributes of park users, a classification representing the use frequency and duration was applied. For example, the responses regarding use frequency were scored as daily (6), several times per week (5), weekly (4), 1-3 times per month (3), monthly (2), several times per year (1) and less (0), and the same principle as used to score the duration of a typical use. The associations of respondents' socioeconomic characteristics with the use frequency and duration per visit were measured using F or *t*-tests via the average scores (Table 6.4 and 6.5). In general, the respondent's age, family status and vocation influenced their use habits the most. Age showed a significant relationship with use frequency and duration. The majority of active users wo reported visiting daily and several times a week belonged to the 46-65 (85.7%) and > 65 age groups (77.4%) (Table 6.4). Also, most respondents from the 46-65 (73.5%) and > 65 age groups (80.6%) expressed that they stayed more than two hours, and some even half a day per visit (Table 6.5). Children were another factor infuencing the use frequency as revealed by the fact that respondents who had children visited green spaces more actively than their childless peers (82.3% versus 73.6%). In addition to age, vocation was also a factor affecting the stay time per visit in green spaces. Retirees prefered to stay significantly longer per visit than the other respondents, and 42.9% stated that they spent nearly half a day in green spaces at a time (Table 6.5). Most of the respondents in the >65 group were retirees. In summary, the major user groups of green sapces in Xi'an were older respondents, as well as unemployed or retired females who have children living with them.

In addition, although over half of the respondents (262 versus 428) spent less than 15 minues on their way to the green space and simultaneously used the green space several times a week or even daily, no significant relatioship was found between the distance and use frequency using the chi-suqared test ($x^2 = 9.877$, $P > 0.05$). Over half of the repondents (218 vs. 428) stayed one to two hours and even longer per visit in the short-distance parks (< 15 minutes away). However, there was also no significant relationship between them ($x^2 = 14.821$, $p > 0.05$).

Table 6.3 Use frequencies, times and durations of visits to green spaces

Category		Survey results (%)		
Time spent on the way	≤5 min	22.0		
	6-15 min	54.0		
	16-30 min	20.0		
	> 30 min	4.0		
Use frequency	Daily	30.4		
	Several times per week	48.6		
	Weekly	14.7		
	1-3 times per month	4.9		
	Monthly	1.4		
	Several times per year	0		
	Less	0		
Duration of use	Less than one hour	30.1		
	One to two hours	52.1		
	Half a day	15.7		
	Whole day	2.1		
		Very often	Often	Occasionally
Time of the day	In the morning (before 12:00)	39.0	54.4	6.5
	In the afternoon (12:00-18:00)	7.5	37.9	54.7
	In the evening (after 18:00)	42.5	45.6	11.9
Time of the week	Weekdays	36.7	56.8	6.5
	Weekends	43.7	50.7	5.6

Table 6.4 Use frequency by socioeconomic variables

Variable	Category	Average score of use frequency	F or t-statistic	*p*-value
Gender	Male	4.96	*t* = -1.2638	0.2070
	Female	5.07		
Age	15-25	4.91	F = 3.26	0.0214*
	26-45	4.91		
	46-65	5.19		
	>65	5.06		
Children	No	4.89	*t* = -2.3492	0.0193*
	Yes	5.09		
Vocation	Student	4.88	F = 0.87	0.4816
	Employed	4.99		
	Self-employed	5.06		
	Unemployed	5.21		
	Retiree	5.12		

Average score: daily = 6, several times per week = 5, weekly = 4, 1-3 times per month = 3, monthly = 2, several times per year = 1, less = 0;
Significant at 0.05 level (*$p < 0.05$)

Table 6.5 Duration per visit by socioeconomic variables

Variable	Category	Average score of duration per visit	F or t-statistic	*p*-value
Gender	Male	1.87	t = -0.7944	0.4274
	Female	1.93		
Age	15-25	1.79	F = 3.62	0.0132*
	26-45	1.80		
	46-65	2.03		
	>65	2.03		
Children	No	1.88	T = -0.4419	0.6588
	Yes	1.91		
Vocation	Student	1.85	F = 3.61	0.0066*
	Employed	1.85		
	Self-employed	1.85		
	Unemployed	1.83		
	Retiree	2.26		

Average score: less than one hour =1, one to two hours = 2, half a day =3, nearly a whole day = 4;
Significant at 0.05 level (*$p < 0.05$)

6.2.3 Citizens' Use Frequency and Duration of Visits, and Variations among Park Variables

Similar with the analysis of social groups, the associations of park characteristics with the use frequency and duration per visit were also measured by F or *t*-tests via the average scores (Tables 6.6 and 6.7). Generally, park area, age and location did not have a significant influence on people's use frequency and stay time. However, tree cover and evergreen species cover showed significant correlations with people's use frequency (see Table 6.6). Multi-layered vegetation cover had a significant influence on peoples' stay time per visit (see Table 6.7). The parks having 26-50% of tree coverage were used often by 83.2% of respondents. The percentage of frequent use decreased with increasing coverage of trees. Only 64.5% of respondents stated to frequently use the parks with 76-100% of tree cover (X^2 = 13.120, p = 0.041). The variations of use frequency in connection with the coverage by evergreen species were very small, even if there were significant relationships between them and high use frequency in the parks with 26-50% of evergreens. In addition, 28.7% of the respondents declared that they would stay more than two hours when they visited the green spaces with 51-75% of multi-layered vegetation. The percentage of such respondents decreased to 13.7% and 14.4% in the parks with 76-100% and 26-50% of multi-layered vegetation, respectively (X^2 = 13.248, p = 0.039).

Table 6.6 Use frequency by variables of park characteristics

Variable	Category	Average score of use frequency	F or t-statistic	*p*-value
Park area (ha)	30-60	5.04	F = 0.146	0.932
	10-30	4.96		
	5-10	5.01		
	0-5	5.02		
Park age	>1990s	5.05	t = 1.755	0.186
	<1990s	4.93		
Location	Within the third ring road	5.07	t = 1.797	0.181
	Within the second ring road	4.95		
Vegetation and water	51-75%	4.99	t = 0.168	0.682
	76-100%	5.03		
Multi-layered vegetation	26-50%	5.07	F = 2.542	0.080
	51-75%	4.85		
	76-100%	5.07		
Tree cover	26-50%	5.11	F = 4.575	0.011*
	51-75%	4.99		
	76-100%	4.77		
Mature tree cover	0-25%	5.05	F = 2.846	0.059
	26-50%	5.12		
	51-75%	4.78		
Evergreen cover	0-25%	4.84	F = 4.656	0.003*
	26-50%	5.18		
	51-75%	4.92		
	76-100%	4.73		

Average score: daily = 6, several times per week = 5, weekly = 4, 1-3 times per month = 3, monthly = 2, several times per year = 1, less = 0;

Significant at 0.05 level (*$p < 0.05$)

Table 6.7 Duration per visit by variables of park characteristics

Variable	Category	Average score of stay time per visit	F or t-statistic	*p*-value
Park area (ha)	30-60	1.94	F = 1.96	0.119
	10-30	2.00		
	5-10	1.79		
	0-5	1.77		
Park age	>1990s	1.87	t = 1.634	0.202
	<1990s	1.96		
Location	Within the third ring road	1.87	t = 0.563	0.453
	Within the second ring road	1.93		
Vegetation and water	51-75%	1.89	t = 0.045	0.832
	76-100%	1.90		
Multi-layered vegetation	26-50%	1.86	F = 3.975	0.019*
	51-75%	2.06		
	76-100%	1.82		
Tree cover	26-50%	1.89	F = 0.622	0.537
	51-75%	1.95		
	76-100%	1.84		
Mature tree cover	0-25%	1.87	F = 2.206	0.111
	26-50%	2.10		
	51-75%	1.88		
Evergreen cover	0-25%	1.95	F = 0.611	0.608
	26-50%	1.91		
	51-75%	1.84		
	76-100%	2.00		

Average score: less than one hour = 1, one to two hours = 2, half a day = 3, nearly a whole day = 4;

Significant at 0.05 level ($*p < 0.05$)

6.3 Citizens' Recreational Activities in Green Spaces

6.3.1 Citizens' Recreational Activities in Green Spaces and Socioeconomic Differences

In order to investigate the respondents' recreational activities in green spaces, the degree of activities was measured by a simple ranking exercise (Table 6.8 and Figure 6.1). The responses to each item in the survey were ranked with scores of very important (2), important (1), neither important nor unimportant (0), and not important (-1). In general, the average scores of recreational activities ranged from 0.07 to 1.45 (Table 6.8 and Figure 6.1). The top three most important activities were all passive in nature, and included enjoying the scenery (1.46), spending time near large greenery (1.38) and contact with nature (1.30). To enjoy the weather and get fresh air (1.22), to do sports (1.18), to relax (1.16), to spend time in quiet and peaceful areas (0.9) and to enjoy the cool in summer (0.8) were ranked as less important. The average scores of the last two activities dropped dramaticly, to 0.16 (to walk a dog) and 0.07 (to use recreational facilites).

The proportion of the "very important" answer for each item was less than 50%, with the highest for beautiful views (47.4%). Only 7.0% of respondents considered the use of recreational facilities, and 6.8% walking a dog as very important. However, ten activities were rated as important by over half of respondents - all but the two least important ones (see Table 6.8).

The importance of recreational activities in green spaces was measured by summing the scores of the 12 items and comparing them with socioeconomic variables using F or t-tests (Table 6.9). In general, males, older citizens, retirees and respondents who have children considered all the recreational activities more important than other use groups. Age and vocation showed a significant relationship (Table 6.9). For example, the use of recreational facilities accounted for 80.6% of the > 65 age group, but only 32.3%, 37.4% and 44.9% in the 15-25, 26-45 and 46-65 age groups, respectively (x^2 = 144.476, $p < 0.001$). In addition, the middle-aged respondents (25.2%) paid more attention to quiet and peaceful spaces than their younger counterparts (16.2%) (x^2 = 27.177, $p = 0.001$).

Table 6.8 Main reasons to use green spaces for recreation (percentage)

Reason	Very important	Important	Not important	Neither important nor unimportant	Average score	Standard deviation
To enjoy the beautiful views	47.4	51.4	0.5	0.7	1.46	0.76
To enjoy large greenery	43.2	53.0	1.6	2.1	1.38	0.77
To get into contact with nature	39.3	54.4	2.6	3.7	1.30	0.74
To enjoy the weather and get fresh air	32.2	61.7	3.7	2.3	1.22	0.72
To do sports	33.6	56.3	5.8	4.2	1.18	0.75
To relax / to reduce the stress	33.2	56.3	6.5	4.0	1.16	0.75
To have fun with friends or play with family	32.0	55.6	6.8	5.6	1.13	0.76
To learn about plants and animals	29.0	58.6	5.6	6.8	1.11	0.75
To spend time in quiet and peaceful areas	26.6	50.2	13.6	9.6	0.90	0.82
To enjoy the cooler air in summer	21.0	52.8	15.4	10.7	0.80	0.81
To walk a dog	6.8	37.9	35.0	20.3	0.16	0.86
To use the recreational facilities (e.g. fitness equipment)	7.0	35.3	42.3	15.4	0.07	0.83

Average score: very important = 2, important = 1, neither important nor unimportant = 0, not important = -1

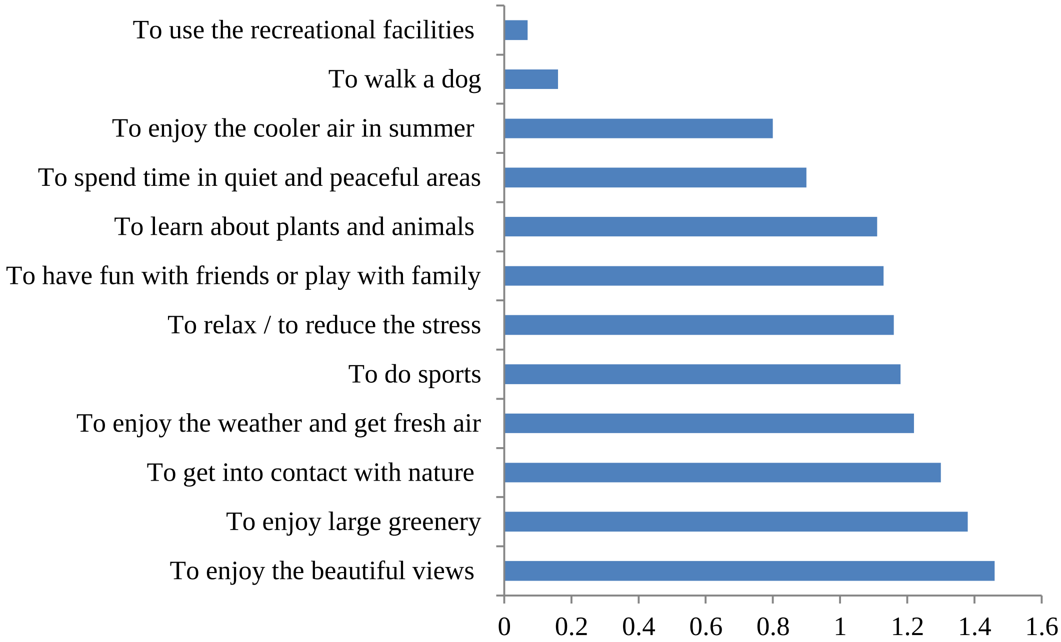

Figure 6.1 Mean rankings of main recreational activities in green spaces

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1

Table 6.9 Activities in green spaces by respondents' socioeconomic variables

Variable	Category	Importance of aims by average score	F or t-statistic	*P*-value
Gender	Male	12.01	t = 0.9759	0.3297
	Female	11.72		
Age	15-25	11.12	F = 3.28	0.0209*
	26-45	11.69		
	46-65	12.24		
	>65	12.81		
Children	No	11.76	t = -0.5724	0.5673
	Yes	11.93		
Vocation	Student	11.00	F = 2.89	0.0222*
	Employed	11.71		
	Self-employed	12.52		
	Unemployed	11.76		
	Retiree	12.88		

Average score = sum of the score of 12 activities;

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1;

Significance at 0.05 level (*$p < 0.05$)

6.3.2 Citizens' Recreational Activities in Green Spaces and Differences of Park Variables

The associations of recreational activities and park characteristics were also analyzed using F or T-tests. Park area had a significant relationship with respondents' recreational activities, including the preferences to do sports, to relax, to learn about plants and animals and to walk a dog (see Table 6.10). The percentages of respondents' preferences for the above activities in the larger parks were larger than in the smaller parks. For example, in the parks with areas of 30-60 ha, 94.7% of respondents considered that doing sports was a very important or important recreational activity. Accordingly, this percentage decreased to 78.2% in the parks with areas of 10-30 ha (x^2 = 28.416, p = 0.001). Similarly, more respondents (78.5%) from the parks with areas of 30-60 ha considered that enjoying cool air in summer was an important aspect of green spaces, while only 46.5% of respondents from smaller parks (0 -5 ha) (x^2 = 32.322, p <0.001) considered the same. Additionally, 23.1% of respondents preferred to walk a dog in the bigger parks with 30-60 ha of area. This percentage was obviously larger than in the smaller parks with 0-5 ha of area (4.2%) (x^2 = 17.435, p = 0.042).

Park age also had a significant relationship with respondents' activities in parks, such as to enjoy peace and quiet, to enjoy larger greenery, to be in contact with nature, to learn about plants and animals and to walk a dog (see Table 6.10). In the newer parks built after the 1990s, 80.1% of the respondents deemed having peace and quiet as important. By comparison, 70% held the same view in the older parks, which were built prior to the 1990s (x^2 = 11.779, p = 0.008). In the newer parks, 92.1% of the respondents wanted to learn about plants and animals, compared to only 77.9% in older parks (x^2 = 21.284, p <0.001). In addition, more respondents preferred to walk a dog in newer parks (49.3%) than in older parks (34.5%) (x^2 = 11.982, p = 0.007), and they considered contact with nature as more important in the newer parks (95.2%) than in the older parks (90.4%). However, all the respondents considered that enjoying large greenery is an important activity in the older parks, while the percentage in the newer parks was 98.3%.

Moreover, the percentage of multi-layered vegetation and evergreen species had a significant influence on respondents' preferred recreational activities including the preference to do sports, to relax, to have fun with family, to enjoy nice weather and get fresh air, to enjoy cool air in the summer and to walk a dog (see Table 6.10). For example, in the parks with 26-50% of multi-layered vegetation, 94% of the respondents preferred to do sports. The percentage decreased to 82.4% in the parks with 51-75% of multi-layered vegetation (x^2 = 12.850, p = 0.045). 96.2% of respondents preferred to relax in the parks with 26-50% of multi-layered vegetation, compared to only 86.2% in the parks with 76-100% of multi-layered vegetation (x^2 = 12.659, p = 0.049). In addition, 59.8% of the respondents preferred to walk a dog in the parks with 26-50% of multi-layered vegetation. This percentage decreased to 38.3% and 37% in the parks with 76-100% and 51-75% of multi-layered vegetation, respectively (x^2 = 21.560, p = 0.001).

Table 6.10 Respondents' recreational activities by variables of park characteristics

Variable	Category	Average score of recreational activities	F or t-statistic	*p*-value
Park area (ha)	30-60	12.54	F = 10.195	<0.001*
	10-30	11.03		
	5-10	11.78		
	0-5	10.26		
Park age	>1990s	12.2	t = 6.502	0.011*
	<1990s	11.12		
Location	Within the third ring road	12.16	t = 1.786	0.182
	Within the second ring road	11.48		
Vegetation and water	51-75%	12.09	t = 1.787	0.182
	76-100%	11.72		
Multi-layered vegetation	26-50%	12.60	F = 3.804	0.023*
	51-75%	11.31		
	76-100%	11.65		
Tree cover	26-50%	11.94	F = 2.171	0.115
	51-75%	12.33		
	76-100%	10.89		
Mature tree cover	0-25%	11.97	F = 1.347	0.261
	26-50%	11.84		
	51-75%	11.31		
Evergreen cover	0-25%	12.63	F=9.135	<0.001*
	26-50%	12.59		
	51-75%	10.78		
	76-100%	11.36		

Average score: sum of the scores of 12 activities;

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1;
Significance at 0.05 level (*$p < 0.05$)

With regard to the influence of evergreen species, it was found that more respondents preferred to do sports, relax, and enjoy cool air in the summer and to walk a dog in the parks with 26-50% of evergreens than in parks with different corresponding area percentages (see Table 6.10). For example, 96.1% of respondents preferred to do sports in the parks with 26-50% of evergreens. The percentage of active respondents decreased to 91.4% and 78.1% in the parks with 0-25% and 76-100% of evergreens, respectively ($x^2 = 18.943$, $p = 0.004$). The respondents' preferences for the other recreational activities had very similar variation (Table 6.10).

6.4 Citizens' Perceptions of Green Spaces

6.4.1 Citizen' Perceptions of Green Space Types and Socioeconomic Differences

When assessing the importance of different types of green spaces without comparing them to each other, 50.2% of respondents first chose the green spaces near their home, school or work place as very important (Table 6.11). 37.4% and 33.4% regarded big suburban parks or parks outside the city areas as very important. Even when first considering their accessibility, a large number of respondents (70.8%) did not avoid big parks except for those that are the farthest.

The analysis of socioeconomic variables showed that older respondents had a statistical association with the perceptions of green space types (Table 6.11). By contrast, the responses of male and female park visitors were nearly the same. Self-employed men rated all types of green spaces as more important than other groups (Table 6.12). The 46-65, 26-45 and 15-25 age groups assessed all types of green spaces as highly important. Nearby green spaces were considered important by all age groups. However, the older age group deemphasized the importance of big city parks and outskirt parks. The "important" option for big city parks was chosen by 64.4% of the respondents > 65, compared to 93.2%, 89% and 79.4% of the 26-65, 26-45, and 15-25 age groups, respectively ($x^2 = 32.588$, $p < 0.01$). In addition, 74.2% of the respondents > 65 regarded outskirt parks as important, compared to 93.1% of the 46-65, 92.8% of the 26-45 and 85.2% of the 15-25 group ($x^2 = 20.230$, $p < 0.05$). Therefore, unlike with other age groups, the elderly only considered the nearby green spaces as important.

Table 6.11 Importance of different types of green spaces (percentage)

Green space	Very important	Important	Not important	Neither important nor unimportant
Near my residence (or work place, school)	50.2	43.9	3.3	2.6
Big city parks, even if farther away	37.4	49.8	6.8	6.1
Parks outside the city	33.4	57.0	4.2	5.4

Table 6.12 Importance of different types of green spaces by socioeconomic variables

Variable	Category	Important types by average score	F or t-statistic	*p*-value
Gender	Male	3.76	t = -0.3029	0.7621
	Female	3.80		
Age	15-25	3.34	F = 6.06	<0.0015*
	26-45	3.87		
	46-65	3.98		
	>65	3.29		
Children	No	3.77	t = -0.0751	0.9402
	Yes	3.78		
Vocation	Student	3.51	F = 1.3	0.2675
	Employed	3.83		
	Self-employed	4.02		
	Unemployed	3.52		
	Retiree	3.71		

Average score = sum of scores of the 3 types of green spaces;

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1;

Significance at 0.05 level (*$p < 0.05$)

6.4.2 Citizen' Attitudes Towards the Importance of Ecosystem Services of Green Spaces and Socioeconomic Differences

To inquire the visitors about the importance of ecosystem services provided by green spaces, a simple ranking exercise was used as described above. A majority of the respondents chose "very important" or "important", with some services rated notably higher (Table 6.13 and Figure 6.2). The average scores of 0.58-1.48 indicated general importance of all 17 ecosystem services, with a majority (11) ranging from 0.6-1.2. The top five services were shading (1.48), O_2 release (1.43), places for recreation (1.32), more contact with nature (1.22) and aesthetic improvement (1.09). By comparison, water-soil conservation (0.85), neighbor-social interaction (0.83), economic value (0.67), wind protection (0.58) and noise reduction (0.58) were ranked the lowest.

The overall perceived importance was measured by summing the scores of the 17 ecosystem services and comparing them with socioeconomic variables using F or t-tests (Table 6.14). The socioeconomic variables did not show a significant association with the importance of any of the ecosystem services. In general, all respondents had similar perceptions regardless of their personal socioeconomic attributes, except for individual services.

Nevertheless, some diffrent perceptions were induced by socioeconomic variables. For example, 22.9% of male respondents deemed species conservation as very important, compared to 28.0% of females (x^2 = 11.963, p = 0.008). Stratified by age group, the assessment of water-soil conservation as "very important" accounted for 25.0% of the respondents from 15-25, in contrast with 15.9%, 14.3% and 12.9% of the 26-45, 46-65 and >65 age groups, respectively (x^2 = 19.163, p = 0.024). Vocation was another factor that influenced the perception of water-soil conservation. 26.8% of students chose "very important", compared to 18.3% of the employed, 14.3% of retirees, 8.7% of the self-employed, and 3.5% of the unemployed respondents (x^2 = 59.306, p <0.001). Therefore, young students valued the importance of water-soil conservation more than other groups. Considering neighbor-social interaction, more respondents who have children (21.9%) tended to choose "very important" than those without children (13.5%) (x^2 = 11.647, p = 0.009).

Table 6.13 Perceptions of the importance of ecosystem services generated by green spaces (percentage)

Ecosystem Service	Very important	Important	Not important	Neither important nor unimportant	Average score	Standard deviation
Shading	50.0	48.4	0.7	0.9	1.48	0.76
O_2 release	44.6	54.0	0.2	1.2	1.43	0.75
Places for recreational activities	40.4	53.5	2.6	3.5	1.32	0.78
More contact with nature	35.0	56.3	4.4	4.2	1.22	0.78
Aesthetic improvement	29.0	59.1	7.7	4.2	1.09	0.78
Wildlife habitats	29.4	54.0	7.2	9.4	1.06	0.81
Species conservation	25.5	59.4	5.6	9.6	1.05	0.79
CO_2 sequestration	23.1	63.1	6.3	7.5	1.03	0.77
Increasing air humidity	25.0	59.4	6.5	9.1	1.03	0.79
Cultural and educational benefits	22.9	58.4	10.3	8.4	0.94	0.80
Air quality improvement	21.8	57.0	11.2	10.1	0.89	0.81
Lower air temperature	23.1	54.9	14.8	7.2	0.86	0.82
Water-soil conservation	16.6	58.2	6.5	18.7	0.85	0.80
Neighbor-social interaction	18.7	57.0	12.9	11.5	0.83	0.81
Economic value (e.g. cultivation of wood and fruits)	14.7	54.2	18.0	13.1	0.67	0.83
Wind protection	11.0	54.0	18.0	17.1	0.58	0.83
Noise reduction	12.4	53.5	19.9	14.3	0.58	0.83

Average score: very important = 2, important = 1, neither important nor unimportant =0, not important = -1

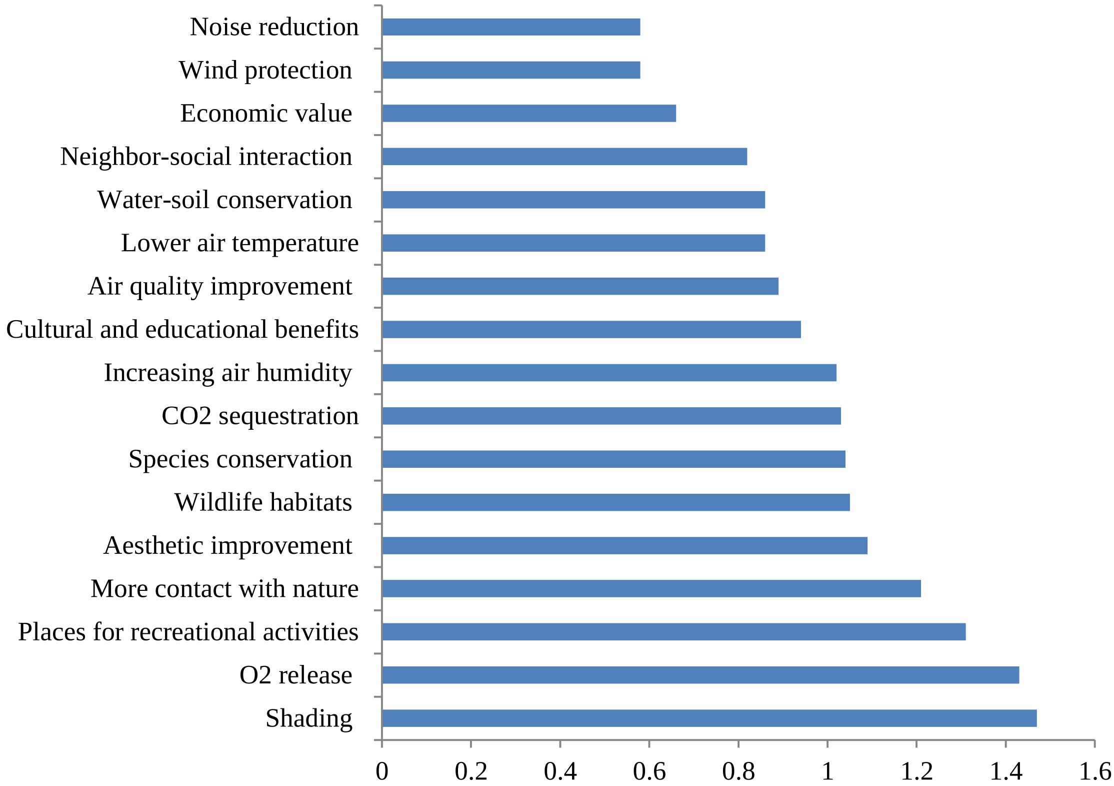

Figure 6.2 Mean rankings of importance of ecosystem services

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1

Table 6.14 Perceptions of the importance of ecosystem services by respondents' socioeconomic variables

Variable	Category	Importance of ecosystem services by average score	F-statistic or t-statistic	*p*-value
Gender	Male	16.94	t = 0.3254	0.7450
	Female	16.81		
Age	15-25	16.81	F = 0.16	0.9246
	26-45	16.96		
	46-65	16.9		
	>65	16.42		
Children	No	17.0	t = 0.3782	0.7054
	Yes	16.82		
Vocation	Student	17.08	F = 0.66	0.6194
	Employed	17.35		
	Self-employed	16.0		
	Unemployed	16.87		
	Retiree	17.14		

Average score: sum of scores of the 17 ecosystem services;

Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1;
Significance at 0.05 level (*$p < 0.05$)

In addition, age and vocation also affected the respondents' perceptions of neighbor-social interaction and economic value. Young students more often disregarded the importance of neighbor-social interaction, while retired people underestimated the economic value of green spaces much more. Although considerable differences and some uncertainty regarding the importance of individual ecosystem services was present, the same perspectives were stated by the overwhelming majority of respondents.

6.4.3 Citizen' Perceptions of the Importance of Ecosystem Services of Green Spaces and Differences of Park Variables

Park area showed a significant relationship with the respondents' perceptions of the importance of ecosystem services, as calculated using the F-test (Table 6.15). For example, park area influenced the respondents' perception of the importance of O_2 release, CO_2 sequestration, wind protection, lower air temperature, noise reduction and aesthetic improvement. Respondents regarded these ecosystem servies as more important in the parks with areas of 10-30 ha and 5-10 ha than in the other parks. For example, 97.5% of respondents thought that aesthetics was important in the parks with areas of 10-30 ha, while this percentage decreased to 76.8% in the parks with areas of 0-5 ha ($x^2 = 18.540$, $p = 0.029$).

Except for the cover of vegetation and water, the other four types of vegetation structure had significant relationships with respondents' perceptions of the importance of ecosystem services. The percentage of multi-layered vegetation influenced the respondents' perception of CO_2 sequestration, wind protection, increased humidity, lower air temperature, and air quality improvement. These ecosystem services were considered as increasingly important with the increasing percentage of multi-layered vegetation cover. For example, in the parks with 26-50% of multi-layered vegetation, 65.2% of the respondents considered that lower air temperature is important, compared to 85.2% and 83.0% in parks with 51-75% and 76-100% of multi-layered vegetation, respectively ($x^2 = 22.987$, $p = 0.001$). Similarly, 86.2% of the respondents in parks with 76-100% of multi-layered vegetation considered that air quality improvement is important. By contrast, only 75.8% and 69.4% of respondents in parks with 26-50% and 51-75% of multi-layered vegetation positively perceived the importance of air quality improvement, respectively ($x^2 = 16.207$, $p = 0.013$).

Table 6.15 Respondents' perceptions of ecosystem services by variables of park characteristics

Variable	Category	Importance of ecosystem services by average score	F or t-statistic	*p*-value
Park area (ha)	30-60	16.20	F = 3.190	0.024*
	10-30	16.88		
	5-10	18.44		
	0-5	16.60		
Park age	>1990s	17.39	t = 0.314	0.576
	<1990s	15.79		
Location	Within the third ring road	17.16	t = 0.157	0.692
	Within the second ring road	16.53		
Vegetation and water	51-75%	17.21	t = 1.333	0.249
	76-100%	16.68		
Multi-layered vegetation	26-50%	15.62	F=15.191	<0.001*
	51-75%	15.67		
	76-100%	18.46		
Tree cover	26-50%	16.96	F=3.585	0.029*
	51-75%	16.43		
	76-100%	17.33		
Mature tree cover	0-25%	17.21	F =11.026	<0.001*
	26-50%	14.29		
	51-75%	17.31		
Evergreen cover	0-25%	13.95	F = 3.058	0.028*
	26-50%	16.94		
	51-75%	17.66		
	76-100%	16.73		

Average score: sum of scores of the 17 ecosystem services;
Very important = 2, important = 1, neither important nor unimportant = 0, not important = -1;
Significance at 0.05 level (*$p < 0.05$)

Tree cover and mature tree cover both obviously influenced the respondents' perceptions of the importance of ecosystem services such as CO_2 sequestration, shading, noise reduction and aesthetic improvement. Ecosystem services were considered more important in parks with a higher cover of trees (76-100%) and mature trees (51-75%). For example, aesthetic improvement was considered more important in the parks with 76-100% than in the parks with 26-50% of trees (100%

versus 84.1%) (x^2 = 17.463, p = 0.008). All respondents valued the importance of shading in the parks with 26-50% and 76-100% of trees, compared to 94.3% in parks with 51-75% of trees (x^2 = 23.967, p = 0.001). Similarly, all respondents regarded shading as important in the parks with 51-75% of mature tree cover. By comparison, this percentage decreased to 92.1% in the parks with 26-50% of mature trees (x^2 = 15.817, p = 0.015).

Similarly, the percentage of evergreen species within the investigated parks also influenced the respondents' perceptions of the importance of ecosystem servcies such as CO_2 sequestration, wind protection, lower air temperature, air quality improvement and aesthetic improvement. More respondents considered these services as important in the parks with 51-75% of evergreens.

6.5 Citizens' Assessments of Green Spaces

6.5.1 Citizens' Assessments of Green Spaces and Socioeconomic Differences

The degree of satisfaction with the investigated 22 parks in Xi'an city was ranked by a simple exercise. The responses to each item were ranked with scores of excellent (3), good (2), fair (1), unclear (0) and poor (-1). For the entirety of green spaces at city level, the first-ranked attribute was management of the green spaces (1.56), followed by the amount of green spaces (1.54), species conservation (1.21), recreational opportunities (1.21) and ecological functions (0.86) (Table 6.16). For all items, more than one fifth, and sometimes even half of respondents chose the "good" option, but less than 11.2% chose "excellent". Considering the proportions of the five options, "good" and "fair" were much more present than "excellent".

The assessment of the entirety of green spaces in Xi'an was measured by comparing the average assessment scores with socioeconomic variables using F or t-tests (Table 6.17). In general, males, older, retired, and respondents who have no children assessed the green spaces more positively. Age showed a significant relationship. For example, 32.3% of the respondents > 65 considered the amount of green spaces excellent, but only 9.52% and 8.79% of the 46-65 and 26-45 groups held the same positive assessment, falling down to zero percent for the 15-25 group, (x^2 = 52.725, $p < 0.05$). However, no > 65 respondents assessed the ecological functions of green spaces as "excellent" (x^2 = 32.103, $p < 0.01$). This reveals that the elderly hold significantly different perceptions than the other groups.

Table 6.16 Assessments of the condition of the entirety of green spaces in Xi'an city (percentage)

Condition of green spaces	Excellent	Good	Fair	Unclear	Poor	Average score	Standard deviation
Management of green spaces	9.3	47.9	37.2	0.5	5.1	1.56	0.81
Amount of green areas	9.3	47.7	36.7	0.2	6.1	1.54	0.81
Species conservation (vegetation and animals)	3.7	38.8	44.4	0.9	12.2	1.21	0.82
Recreational opportunities	11.2	35.5	33.6	2.6	17.1	1.21	0.87
Ecological functions (e.g. decreased temperature, lower air pollution)	1.6	26.2	48.8	3.3	20.1	0.86	0.83

Very important = 2, important = 1, unclear = 0, not important = -1

Table 6.17 Assessment of the condition of the entirety of green spaces in Xi'an by respondents' socioeconomic variables (percentage)

Variable	Category	Average score over the entirety of green spaces	F or t-statistic	*p*-value
Gender	Male	6.47	t = 0.5979	0.5502
	Female	6.29		
Age	15-25	5.66	F = 10.52	<0.0010*
	26-45	6.5		
	46-65	6.02		
	>65	8.97		
Children	No	6.54	t = 0.8630	0.3886
	Yes	6.28		
Vocation	Student	6.20	F = 1.73	0.1419
	Employed	6.26		
	Self-employed	6.04		
	Unemployed	6.59		
	Retiree	7.39		

Average score: sum of scores of the 5 aspects;

Very important = 2, important = 1, unclear = 0, not important = -1;

Significant at 0.05 level (*$p < 0.05$)

For the green spaces used daily by the citizens, the average score of assessment ranged from 0.15 to 1.98 (Table 6.18 and Figure 6.3). Half of the ratings were in the range of 1.0-1.5. Vegetation coverage received the highest assessment (1.98), followed by microclimate (1.84) and overall performance (1.63). The lowest was air quality (0.74), water area (0.73) and water quality (0.15).

Similar with the entirety of green spaces, the amount of green areas and management of the green spaces used daily by the study participants also received higher assessments than the recreational opportunities, species conservation, and ecological functions. Only 6.8% of respondents had the impression that their daily-used parks performed excellently as a whole. When viewing each specific item, the highest percentage of “excellent” assessments was of vegetation coverage, which accounted for no more than 23.8%. By contrast, “good” assessments occupied the majority. Over half of the respondents ranked vegetation coverage (55.4%), cleanliness (55.4%) and microclimate (52.8%) as good. Especially, the overall performance of the parks received good assessments in 55.8% of the cases. On the other end of the spectrum, water quality received poor assessments in 46.7% of the cases. Dissatisfaction with the area of water bodies also accounted for 34.6%. In addition, sporting facilities were viewed as being in poor condition by 27.1% of respondents. Air quality and the number of wild animals were considered poor by 24.1% and 22.2% of respondents, respectively.

The assessments of all the 22 parks were analyzed by summing up the average scores of 20 assessment aspects and comparing them with socioeconomic variables using F or t-tests (Table 6.19). There was no significant difference between the assessments based on gender / age group / vocation. However, family status showed statistical significance. For example, 87.11% of the respondents without children positively assessed the vegetation cover of green spaces, compared to only 74.34% of those with children (x^2 = 15.166, p = 0.004). Positive assessments for playgrounds from the respondents with children were more prominent than from those without children (46.01% and 37.74%) (x^2 = 22.410, p <0.001). In addition, only 18.87% of respondents who have children positively assessed air quality, compared to 28.22% of their childless peers (x^2 = 12.295, p = 0.002).

Table 6.18 Assessments of green spaces used daily by the citizens (percentage)

	Excellent	Good	Fair	Unclear	Poor	Average score	Standard deviation
Management of the green space							
Cleanliness	9.4	55.4	29.0	0.5	5.8	1.62	0.80
Safety	3.0	38.1	48.1	1.4	9.4	1.24	0.81
Amount of green areas							
Vegetation cover ratio	23.8	55.4	18.2	0.5	2.1	1.98	0.80
Species conservation							
The number of vegetation types	9.4	43.0	35.1	3.5	9.1	1.40	0.84
The number of wild animal species (e.g. birds or insects)	1.9	22.4	48.6	4.9	22.2	0.77	0.83
Recreational opportunities							
Scenic beauty	10.3	39.0	41.1	1.6	7.9	1.42	0.83
The number of sporting facilities	4.0	23.6	44.4	0.9	27.1	0.77	0.84
The location of sporting facilities	4.4	35.7	48.6	1.2	10.1	1.23	0.81
The maintenance of sporting facilities	2.6	35.5	46.7	1.4	13.8	1.12	0.82
The number of resting facilities (e.g. tables or benches)	0.5	28.7	52.3	1.6	16.8	0.94	0.81
The location of resting facilities (e.g. tables or benches)	1.4	37.2	52.1	1.4	7.9	1.23	0.79
The maintenance of resting facilities (e.g. tables or benches)	2.6	42.1	47.9	0.2	7.2	1.33	0.79
The area of playgrounds	3.5	37.4	43.9	0.9	14.3	1.15	0.82
The location of playgrounds	3.0	39.0	47.0	0.5	10.5	1.24	0.81
The maintenance of playgrounds	2.6	47.0	44.4	0.7	5.4	1.41	0.79
Ecological functions (e.g. decrease of temperature, lower air pollution)							
Microclimate (e.g. cooling, tree shade, humidity and wind)	18.0	52.8	26.6	0	2.6	1.84	0.81
Air quality	0.5	22.0	52.6	0.9	24.1	0.74	0.81
The area of water bodies	8.2	26.4	30.1	0.7	34.6	0.73	0.87
Water quality (if water bodies are present)	0.5	8.2	43.9	0.7	46.7	0.15	0.79
Overall assessment of the site	6.8	55.8	34.4	0	3.0	1.63	0.78

Excellent = 3, good = 2, fair = 1, unclear = 0, poor = -1

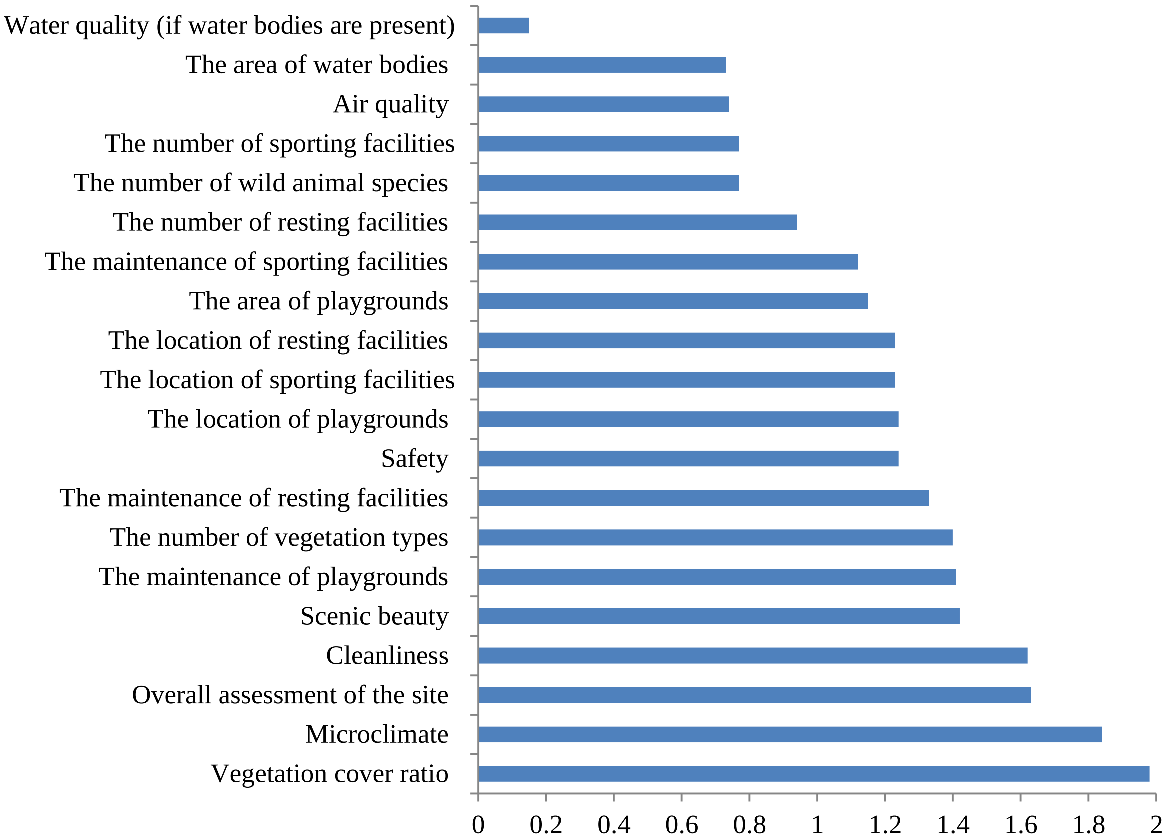

Figure 6.3 Mean rankings of the assessments

Excellent = 3, good = 2, fair = 1, unclear = 0, poor = -1

Table 6.19 Assessments of green spaces used daily by the respondents based on socioeconomic variables

Variable	Category	Average score of daily used green spaces	F or t-statistic	*p*-value
Gender	Male	24.11	t = 0.5656	0.5720
	Female	23.73		
Age	15-25	24.37	F = 0.86	0.4641
	26-45	24.09		
	46-65	23.26		
	>65	25.10		
Children	No	24.96	t = 2.4152	0.0161*
	Yes	23.28		
Vocation	Student	26.27	F = 1.97	0.0982
	Employed	23.36		
	Self-employed	23.06		
	Unemployed	24.24		
	Retiree	25.08		

Average score: sum of scores of the 20 aspects;
Excellent = 3, good = 2, fair = 1, unclear = 0, poor = -1;
Significant at 0.05 level (*$p < 0.05$)

6.5.2 Citizens' Assessments of Green Spaces and Differences of Park Variables

Respondents' assessments were significantly influenced by park characteristics, as calculated using the F or t-tests (see Table 6.20). Considering the park area, it was shown that more positive assessments were given for the parks with areas of 10-30 ha and 0-5 ha, followed by the parks of 30-60 ha and 5-10 ha (see Table 6.20). For example, 88.5% of the respondents were satisfied with the vegetation cover in the parks having 10-30 ha of area, followed by 86% in the parks with 0-5 ha. This percentage decreased to 83.7% and 72.2% in the parks with areas of 5-10 ha and 30-60 ha, respectively ($x^2 = 25.451$, $p = 0.013$). Similarly, in the parks with areas of 10-30 ha, 60.3% of the respondents felt satisfaction with the scenery. By contrast, in parks with areas of 5-10 ha, the satisfaction dropped to 29.6% ($x^2 = 36.317$, $p < 0.001$).

Park age also significantly influenced many of the respondents' assessments of features such as vegetation cover, microclimate, the number of vegetation types, scenic beauty, the number of resting facilities, the location of sporting facilities, resting facilities and playgrounds, and the maintenance of sporting facilities and playgrounds. Usually, the percent of positive assessments increased with the increasing age of parks. For example, 72.1% of respondents deemed that the number of types of vegetation was sufficient in the older parks, which were built prior to the 1990s. However, only 43.2% of the respondents held the same position in the newer parks ($x^2 = 41.083$, $p < 0.001$). Similarly, respondents' assessments of the above-referred items were very similar to the assessments of vegetation types.

The parks' location also significantly influenced the respondents' assessments of green spaces, including features such as the vegetation cover, microclimate, the number of vegetation types and animal species, scenic beauty and the location and maintenance of sports facilities. In most cases, the respondents much more positively assessed the related items in parks that were located within the second ring road than in the parks that were located within the third ring road. For example, 86.4% of the respondents positively assessed the vegetation cover of the parks located inside the second ring road, compared to 73.4% of those located inside the third ring road ($x^2 = 22.383$, $p < 0.001$).

Vegetation structure types including multi-layered vegetation, trees, mature trees and evergreen species had significant relationships with respondents' assessments of green spaces. Usually, the more positive assessments for urban parks, such as the vegetation cover, microclimate, the vegetation types, scenic beauty, safety, the number of sports facilities, and the areas and location of playgrounds were correlated with 51-75% of multi-layered vegetation. For example, in the parks with 51-75% of multi-layered vegetation, 95.4% of respondents were satisfied with the cover of vegetation. By comparison, the satisfaction decreased to 81.9% and 62.1% in the parks with 76-100% and 26-50% of multi-layered vegetation, respectively (x^2 = 65.424, p <0.001). Similarly, in the parks with 51-75% of multi-layered vegetation, 74.1% of respondents highly assessed the scenery. However, such assessments dropped to 34.9% in the parks with 26-50% of multi-layered vegetation (x^2 = 72.816, p <0.001).

Table 6.20 Respondents' assessments by variables of park characteristics

Variable	Category	Average score of respondents' assessments	F or t-statistic	*p*-value
Park area (ha)	30-60	23.81	F = 6.886	<0.001*
	10-30	26.45		
	5-10	21.88		
	0-5	24.58		
Park age	>1990s	22.89	t = 20.472	<0.001*
	<1990s	26.14		
Location	Within the Third Ring Road	22.85	t = 11.660	0.001*
	Within the Second Ring Road	25.26		
Vegetation and water	51-75%	24.61	t = 1.656	0.199
	76-100%	23.51		
Multi-layered vegetation	26-50%	22.14	F = 30.621	<0.001*
	51-75%	28.09		
	76-100%	22.78		
Tree cover	26-50%	22.66	F = 9.403	<0.001*
	51-75%	24.64		
	76-100%	26.46		
Mature tree cover	0-25%	23.36	F = 3.590	0.028*
	26-50%	25.92		
	51-75%	25.11		
Evergreen cover	0-25%	19.93	F = 22.188	<0.001*
	26-50%	22.33		
	51-75%	27.14		
	76-100%	23.94		

Average score: sum of scores of the 20 aspects;
Excellent = 3, good = 2, fair = 1, unclear = 0, poor = -1;
Significant at 0.05 level (*$p < 0.05$)

It was also obvious that parks with 76-100% of trees and 26-50% of mature trees received more positive assessments regarding the above-referred features. For instance, in the parks with 76-100% of trees, 92.4% of the respondents were satisfied with the vegetation cover, compared with only 71.8% of satisfaction in the parks with 26-50% of trees ($x^2 = 28.162$, $p < 0.001$). Similarly, 93.8% of the respondents were satisfied with the vegetation cover in the parks with 51-75% of mature trees. By contrast, the percentage of satisfaction dropped to 74.4% in the parks with 0-25% of mature trees ($x^2 = 20.991$, $p = 0.007$). However, the highest assessment of scenery was 74.5% in the parks with 26-50% of mature trees, and the lowest was 35.9% in the parks with 76-100% of mature trees ($x^2 = 39.718$, $p < 0.001$).

Furthermore, evergreen species influenced the respondents' assessments of all the above-mentioned features in urban parks. The parks with a medium percentage (51-75%) of evergreens usually received more positive assessments than the other parks. For example, 65.1% of positive assessments of the scenery were given for parks with 51-75% of evergreens, while only 30.2% and 21.2% of positive assessments were given for parks with 0-25% and 76-100% of evergreens, respectively ($x^2 = 69.771$, $p < 0.001$).

6.6 Citizens' Demands for Green Spaces

6.6.1 Citizens' Demands for Green Spaces and Socioeconomic Differences

Rank scores were given according to the assessments: strongly need (2), need (1), neither need nor not need (0), and do not need (-1) in order to investigate the demand for specific features in green spaces. The top demands for urban green spaces with average scores ≥ 1 were more shade (1.19), more opportunities to watch nature (1.14), more flowers (1.06) and better management (1.02) (Table 6.21 and Figure 6.4). More facilities for sports and exercise (0.92), more play areas for children (0.89), more resting facilities (e.g. benches/tables) (0.88), more quiet places (0.69), more water bodies (0.68), as well as more convenient and safer transportation (0.64), were ranked in the class of less important demands. Very few respondents felt they needed more cafes or restaurants (0.37) and quiet places (0.16).

Specifically, over half of the respondents declared that they strongly needed more shade and more opportunities to watch nature (Table 6.21). Additionally, over half of the respondents expressed moderate needs for more flowers (55.6%), more play areas for children (56.7%), more sporting facilities (56.6%), more resting facilities (54.2%) and better management (59.8%) (Table 6.21).

Table 6.21 Respondents' demands for specific features in urban green spaces (percentage)

Ecosystem service	Strongly need	Need	Do not need	Do not care	Average score	Standard deviation
More shade	50.5	22.0	4.4	23.1	1.19	0.84
More wind-protected sites	23.4	2.6	33.4	40.7	0.16	0.86
More water bodies	36.2	12.9	17.5	33.4	0.68	0.90
More opportunities to watch nature (birds, plants, etc.)	50.5	20.8	7.7	21.0	1.14	0.84
More flowers	48.1	17.5	8.2	26.2	1.06	0.85
More quiet places	40.0	8.2	19.2	32.7	0.69	0.88
More facilities for sports and exercise	46.3	10.3	10.5	32.9	0.92	0.85
More play areas for children	45.3	11.4	13.3	29.9	0.89	0.86
More resting facilities (e.g. benches / tables)	43.9	10.3	9.8	36.0	0.88	0.85
More cafes / restaurants	29.7	3.7	26.2	40.4	0.37	0.87
More convenient and safer transportation to the green spaces	37.1	5.6	15.7	41.6	0.64	0.85
Better management (e.g. better maintenance of plantings, facilities / less litter)	49.5	10.3	7.5	32.7	1.02	0.83

Strongly need = 2, need = 1, do not care = 0, do not need = -1

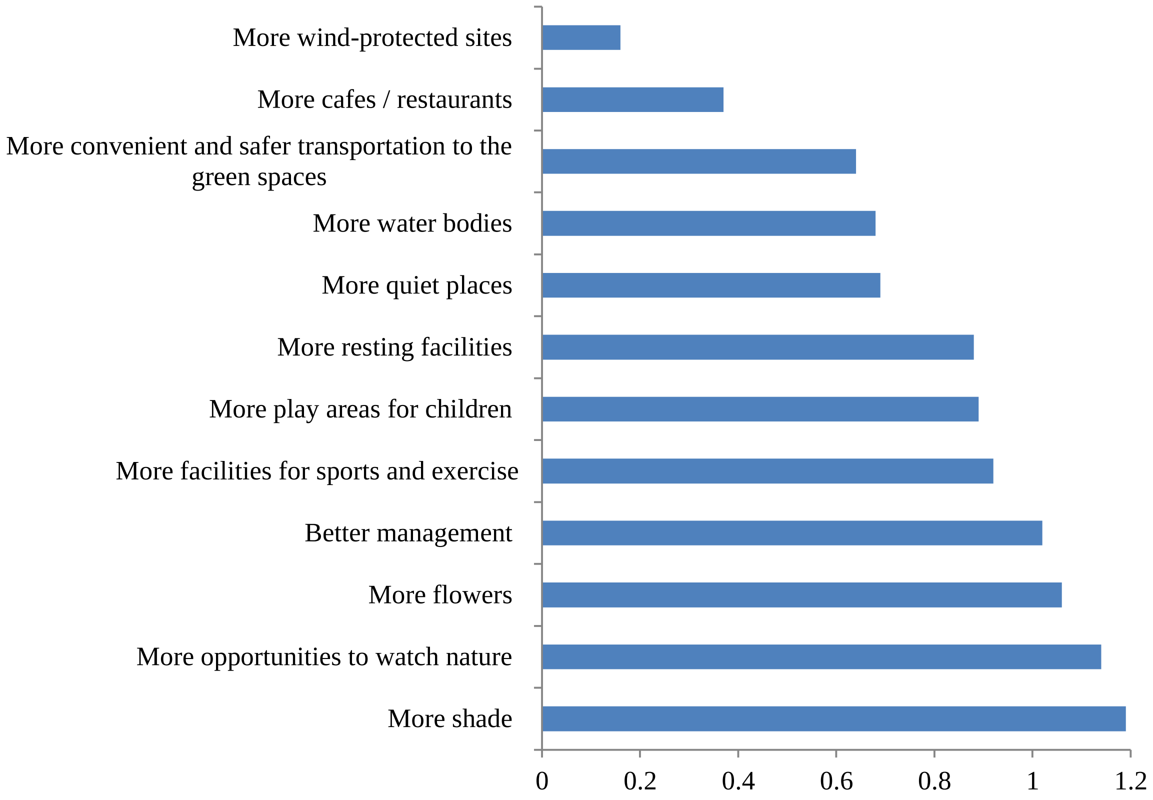

Figure 6.4 Mean rankings of the survey respondents' demands for specific features in urban green spaces

Strongly need = 2, need = 1, do not care = 0, do not need = -1

The association between demands for specific features in green spaces and socioeconomic variables was measured by F or t-tests, whereby the 12 aspects were summed using their average scores (Table 6.22). In general, young, male students had stronger demands for the referred twelve features in green spaces. Moreover, age and vocation showed significant statistical associations with demands. For example, more quiet places were strongly needed by 32.3% of the > 65 respondents, but only 16.2%, 6.8% and 6.6% of the 15-25, 26-45 and 46-65 age groups, respectively ($x^2 = 43.914$, p <0.001). In addition, the middle-aged (22.0% and 32.0%) and older respondents (29.0%) wanted more children's play areas than did the young (8.8%) ($x^2 = 39.419$, p <0.001). Notably, with increased age, respondents' strong need for cafes and restaurants decreased from 23.5% (15-25) to 0% (> 65) ($x^2 = 116.462$, p <0.001). A larger percentage of employed respondents (14.83%) wanted cafes and restaurants than those belonging to the other groups ($x^2 = 59.466$, p <0.001). The largest proportion (22.5%) of strong need for more quiet spaces came from retired respondents ($x^2 = 26.689$, $p = 0.009$). At the same time, strong need for resting facilities was mainly expressed by retired (22.45%) and unemployed respondents

(13.79%) (x^2 = 26.738, p = 0.008). In addition, students expressed a much stronger need for sporting facilities (56.1%) than other vocations (x^2 = 79.449, p <0.001). Perhaps unsurprisingly, they expressed the least need for children's play areas (7.3%) (x^2 = 25.951, p = 0.011). The results revealed that the demands of young students were different from those of the other respondents.

Table 6.22 Respondents' demands by socioeconomic variables

Variable	Category	Average score of daily-used green spaces	F or t-statistic	*p*-value
Gender	Male	10.44	t = 0.3824	0.7023
	Female	10.28		
Age	15-25	11.38	F = 4.85	0.0025*
	26-45	10.81		
	46-65	9.71		
	>65	8.52		
Children	No	10.41	t = 0.1964	0.8444
	Yes	10.32		
Vocation	Self-employed	9.61	F = 2.82	0.0248*
	Employed	10.53		
	Unemployed	9.34		
	Retiree	9.39		
	Student	11.98		

Average score: sum of scores of the 12 demand categories;
Strongly need = 2, need = 1, do not care = 0, do not need = -1;
Significant at 0.05 level (*p < 0.05)

6.6.2 Citizens' Demands for Green Spaces and Differences of Park Variables

The relationships between citizens' demands and park characteristics were also analyzed using F or t-tests (Table 6.23). It was found that park age and location significantly influenced the respondents' demands for specific features in green spaces, in addition to the cover of multi-layered vegetation, trees and evergreen species.

In the older parks located within the second ring road, the respondents voiced more demands for ecosystem services provided by green spaces. 76.2% of the respondents thought that the older parks needed to be managed better. The percentage of respondents who raised the same demands decreased 10% in the newer parks (x^2 = 9.814, p = 0.020). While in the newer parks which were built after the 1990s, 76.4%

of the respondents expressed the need for more shade, this percentage was 64% in the older parks ($x^2 = 19.299$, $p < 0.001$). In addition, the respondents expressed more need for safe spaces in the parks located within the second ring road than in those inside the third ring road (80.1% versus 62.8%) ($x^2 = 8.554$, $p = 0.036$).

Table 6.23 Respondents' demands by variables of the parks' characteristics

Variable	Category	Average score of respondents' demands	F or t-statistic	*p*-value
Park area (ha)	30-60	7.59	F = 0.191	0.663
	10-30	6.51		
	5-10	9.96		
	0-5	7.02		
Park age	>1990s	7.71	t = 4.890	0.028*
	<1990s	8.24		
Location	Within the third ring road	7.83	t = 6.420	0.012*
	Within the second ring road	7.94		
Vegetation and water	51-75%	7.31	t = 0.419	0.518
	76-100%	8.22		
Multi-layered vegetation	26-50%	8.56	F = 4.432	0.012*
	51-75%	7.04		
	76-100%	7.88		
Tree cover	26-50%	8.03	F = 8.655	<0.001*
	51-75%	6.70		
	76-100%	9.28		
Mature tree cover	0-25%	7.50	F = 1.029	0.358
	26-50%	8.18		
	51-75%	9.50		
Evergreen cover	0-25%	6.47	F = 4.666	0.003*
	26-50%	8.88		
	51-75%	6.80		
	76-100%	8.61		

Average score: sum of scores of the 12 demand categories;
Strongly need = 2, need = 1, do not care = 0, do not need = -1;
Significant at 0.05 level (*$p < 0.05$)

Moreover, respondents from the parks with a lower cover of multi-layered vegetation and evergreens, and higher cover of trees, expressed different demands for the referred ecosystem services. For example, in the parks with 26-50% of multi-layered vegetation, 75.7% of the respondents wished there were more shade, in comparison to 71.8% and 69.4% of respondents from the parks with 76-100% and 51-75% of multi-layered vegetation, respectively (x^2 = 15.439, p = 0.017). Evergreen cover also influenced the respondents' need for shading. 73.8% of the stronger need came from the parks with 0-25% of evergreens. The need decreased to 64.7% in the parks with 26-50% of evergreens (x^2 = 20.465, p = 0.015).

The cover of trees influenced the respondents' needs for shading, wind-protected sites, quiet spaces and park management. For example, 73.5% of the respondents from the parks with 76-100% of trees expressed a stronger wish for more flowers. This preference decreased to 68.2% and 55.8% in the parks with 26-50% and 51-75% of trees, respectively (x^2 = 18.696, p = 0.005). Respondents from the parks with 0-25% of mature trees wanted more shading (73.8%) than those from parks with 26-50% of mature trees (64.7%) (x^2 = 27.249, p <0.001).

6.7 Discussion

6.7.1 Discussion of the Respondents' Green Space Use Behaviors

6.7.1.1 Comparison of Green Space Use Behaviors with Other Studies

In this study, public parks and residential green spaces were the most often visited types of green spaces in Xi'an (Table 6.2). Similarly, public urban parks were the preferred types of outdoor places in a study of Santa Cruz, Bolivia (Wendel et al. 2012). In Guangzhou, the majority of citizens preferred to use the public urban green spaces and newly developed urban green spaces (Shan 2009). Public parks were the most preferred green spaces in different social contexts, probably due to their multi-functional provisions, better maintenance and more amenities.

Respondents in Xi'an were very active in visiting urban green spaces. The majority of respondents visited urban green spaces at least once a week (93.7%) but with a shorter stay - less than one to two hours (82.2%) (Table 6.3). Similarly, a study in Denmark showed that 92% of residents visited a green space at least once a week (Schipperijn et al. 2010). Some other studies also found that citizens visited green spaces more frequently but spent a shorter time on each visit. For example, an intercontinental study conducted in Germany, Chile and Spain found that although residents visitied green spaces frequently, only around half of them stayed more than one hour (Priego et al. 2008). By contrast, the frequency of visits to green spaces was very low in Karachi, and more than half of the respondents stated that they rarely or never visit green spaces in the city (Qureshi et al. 2010). However, although the frequency of use as a whole was low, the duration of visits was fairly long, often involving a stay of multiple hours (Qureshi et al. 2010).

6.7.1.2 The Influence of Socioeconomic Variables on Respondents' Use Behaviors

The differences of use habits could be partly due to socioeconomic differencs in attitudes towards green spaces (Oguz 2000). The frequency of visits to urban green spaces of Xi'an was significantly affected by respondents' age and family status. Older respondents and those who lived with children were more likely to use green spaces frequently. Pincetl et al. (2003) also found that respondents with children were considerably more likely to visit parks. A possible reason is that green spaces may be a suitable place to play with the active children. Many studies have indicated that park use was negatively correlated with age, with older residents reporting less use (Payne et al. 2002; Pincetl 2003; Pincetl and Gearin 2005; Rossi et al. 2016). However, this study and the study of Shan (2009) showed a positive relationship between age and urban green space visitation.

The stay time in green spaces per visit was significantly afftected by age and vocation. Older respondents and retirees stayed markedly longer than the other groups. In Chinese cities, the retirement age is 50-55 for females and 55-60 for males, which means retirees are also older people. The findings that aged respondents visited green spaces more frequently and stayed longer per visit may be because they have more spare time to spend and participate in local lesuire activities. Moreover, older respondents may be constrained by limited recreational activities and lifestyle choices, leaving green spaces as preferred places to spend their spare time. People nowadays have more alternatives to triditional parks, such as fitness centres, cafes and karaoke venues, and these leisure activites are popular with the younger generations.

Furthermore, in this study, no siginificant relationship was found between distance and use frequency or duration. The results may therefore imply that the effect of distance on green space use in Xi'an is less strong than other studies suggested. For example, in Denmark, a detailed comparison between the changes of citizens' use frequency and the distance to nearest green spaces from the home found that the longer the distance, the lower the frequency of use, albeit distant parks with good quality amenities attracted more visitors than closer but simpler parks (Schipperijn et al. 2010). The nearest green space being more than 300 m away was a factor that significantly diminished the citizens' daily use. An investigation of the variations among socioeconomic groups revealed that younger respondents (16-24) were more likely to go to green spaces within a distance of less than 300 m than the age group of 45-65 years (Schipperijn et al. 2010). In this study, the lack of significance of distance may be mainly due to the constrained questionnaires, since 76% of respondents denoted that they usually visited a green space within a distance of 15 minutes from their homes. Moreover, the majority of respondents were active users of green spaces. The results are in agreement with a study by Schipperijn et al, which found that within a relatively near distance, a majority of respondents visited the green spaces frequently (Schipperijn et al. 2010).

In addition, there were other influencing factors such as the facilities and accessibility of parks. In the UK, a study suggested that visitors were attracted by the high quality of green spaces rather than a lack of alternative spaces within a smaller catchment area of visitors' homes (Lafortezza et al. 2009). The relationships between the quality of green spaces in Xi'an city and their use frequency or duration can be discussed in the future, according to research such as the maximum distance that visitors are willing to accept to get to a high-quality green space. Moreover, the relationship of visitors' use frequency and stay time in a higher quality but slightly more distant green space compared to a lower quality but closer green space merits further investigation to better inform the allocation of resources.

6.7.1.3 The Influence of Park Variables on Respondents' Use Behavior

Considering park characteristics, respondents' use habits were not influenced by the variables of park area, age and location, but were influenced by the variables of vegetation structure (see Tables 6.6 and 6.7). Parks with a lower cover of trees and evergreens attracted more visits, while those with medium percentages of multi-layered vegetation had longer stay times. These results may indicate that visitors in Xi'an prefer to use parks with larger open spaces and to stay longer in parks with abundant layers of vegetation with a relatively low density. This corroborates the findings of previous studies which showed that moderately open scenes and an intermediate density of vegetation cover are preferred in green spaces (Bjerke et al. 2006). However, due to the limited number of questionnaires at specific parks, it is impossible to know if the parks with low tree cover and medium cover of multi-layered vegetation meet the use habits of different socioeconomic groups, such as older respondents, females, or students.

6.7.2 Discussion of Respondents' Recreational Activities in Green Spaces

6.7.2.1 A Comparison of Respondents' Recreational Activities with Similar Studies

Citizens of Xi'an embraced multiple recreation activities in urban green spaces. To enjoy the scenery and large greenery and to have contact with nature constituted the top three most important activities (Figure 6.1). By contrast, the use of recreational facilities and walking a dog were the least important (Figure 6.1). Similarly, a study in Guangzhou indicated that cleanliness and beautiful views were the reasons that attracted the most citizens, while seeing birds, other wildlife and water bodies were the least attractive (Chen 2006). In a later study, also in Guangzhou, to breathe fresh air and to enjoy beautiful scenery were the most frequent recreational activities in green spaces, while observing wildlife and taking part in cultural activities were the least popular (Shan 2009). In a number of studies, to walk and to relax and enjoy the scenery were the preferred activities (Casper et al. 2013; Derkzen 2012; Rall et al. 2017). Similar with many other studies, enjoyment of nature and beautiful views was also aspired to by citizens of Xi'an, and the results suggest that the recreational activities and amenities are the primary ecosystem services that the citizens would like to derive from green spaces (Chiesura 2004; Oguz 2000; Sanesi and Chiarello 2006). In this study, over half of the preferred recreation activities in green spaces were of the passive type. A study in Berlin and Salzburg also found that the majority of park visitors tended to do passive activities such as reading, sunbathing, and enjoying the flora and fauna, rather than active activities, such as walking and walking dogs, when they used the parks (Voigt et al. 2014).

On the other hand, the lower inclination to be active, such as to walk, to walk a dog, to do sports or to use recreational facilities, may indicate a shortage of corresponding provisions such as sporting facilities, recreational facilities, playing fields and playgrounds. In Chinese cities, the recreational facilities include some free amenities such as public fitness equipment, sandpits, seesaws and swings, as well as for-pay options such as rides, ferries wheels, boating, and fishing. The low percentage of use of recreational facilities may indicate the poor condition or limited usefulness of the existing facilities. Finally, the fact that walking a dog was not a main recreational activity might simply be due to sample bias, and that not many citizens who have a dog took part in the questionnaire survey.

6.7.2.2 The Influence of Socioeconomic Variables on Respondents' Recreational Activities

People with distinct socioeconomic backgrounds have different preferred recreational activities. In this study, age significantly affected the choice of recreational activities. The older respondents preferred to use the recreational facilities in green spaces more than other groups. The results may again prove that the lifestyle choices of the elderly are limited to the traditional and local recreation opportunities, rather than new popular activities. Age-related differences were also found in a study by Chiesura (2004). Doing sports and meeting friends were more popular among the young. Relaxing and staying with children seem to be preferred by adults and the elderly. In a study from Brazil, older people preferred to walk through the park, middle aged people engaged more in playing with children, and young people were found to prefer team sports (Derkzen 2012). In Guangzhou, the gender and marital status affected the respondents' use aims, such as relaxing and breathing fresh air (Shan 2009). In general, the older respondents in this study enjoyed different activities in green spaces than the other age groups. They tended to take part in more passive activities and use more of the provided facilities in parks than the younger generations. Additionally, the variety of recreation activities mirrors the citizens' demands and expectations of green spaces (Chiesura 2004). This information can be used to develop strategies to meet recreational needs of the public.

6.7.2.3 The Influence of Park Variables on Respondents' Recreational Activities

Respondents' initiative to take part in recreational activities in green spaces increased within the larger and newer parks. This may be due to the fact that the larger and newer parks provide enough space and well-kept facilities for visitors to relax, do sports, enjoy peace and quiet, etc. Recently, park designers have paid more attention to providing various ecosystem services, and especially recreational services. The larger parks can easily achieve these aims due to their larger area. The newer parks have newer facilities and require less effort to achieve satisfactory maintenance.

Additionally, the respondents' preferences for recreational activities were closely connected with the parks which have 26-50% of multi-layered vegetation and evergreen species. A study of green spaces in Iran also found that the majority of recreational activities take place in green spaces with medium density (40-60%) and single-layered vegetation (Aminzadeh and Ghorashi 2007). These results may indicate that respondents prefer to do recreational activities in green spaces with simple vertical structures. Multi-layered vegetation is composed of trees, shrubs and lawns. This composition directly reduces the available space for activities such as sporting, resting and playing with children, because of the barrier presented by shrubs. By contrast, a piece of ground covered by trees or trees over lawn would provide more space for visitors to do different kinds of activities. Generally, this study investigated the respondents' preferred recreational activities, but did not inquire which types of recreational activities are preferably done in which types of vegetation structure.

6.7.3 Discussion of Respondents' Perception of Green Spaces

6.7.3.1 Comparison of Respondents' Perceptions with Similar Studies

In Xi'an, over half of respondents deemed the green spaces near their home as very important (Table 6.11). This finding was in agreements with studies by Shan (2009), Schipperijn et al., (2010) and Li et al., (2011). In this study, the socioeconomic analysis found that age significantly affected this perception. Elderly respondents usually considered the nearby green spaces as more important than their younger counterparts. This observation most likely means that distance would restrict the green space use of older citizens more than in the case of other age groups. Nevertheless, younger citizens in Denmark preferred the nearby green spaces more than their older counterparts (Schipperijn et al. 2010). The results of this study revealed that citizens usually preferred the green spaces near their homes but the socioeconomic variables varied locally.

The questionnaires concerning the ecosystem services usually mentioned cultural services (e.g. tourism, recreation, and aesthetics), regulating services (air purification, climate regulation, water regulation and soil formation) and provisioning services (e.g. water provision and food and material provision) (Casado-Arzuaga et al. 2013; Jim and Chen 2006a). In this study, microclimate regulation (shading and O_2 release) and recreation (places for recreational activities, more contact with nature and aesthetic improvement) were rated as most important (Figure 6.2). These findings conformed to those from other studies. For example, microclimate was ranked as the most important ecosystem service provided by green spaces in Phnom Penh, Cambodia (Yen et al. 2016). By contrast, the aesthetic value of green spaces was regarded as the most important service in Hong Kong, China (Lo and Jim 2010b) and Rotterdam, the Netherlands (Buchel and Frantzeskaki 2015). Additionally, the contribution of green spaces to contact with nature was stressed most in a study by Pincetl and Gearin (2005).

However, these findings also showed some differences compared with similar studies. Studies conducted in various countries such as Uganda (Hartter 2010), Uruguay (Vihervaara et al. 2012), Spain (Casado-Arzuaga et al. 2013; Castro et al. 2011) and cities such as Hong Kong (Lo and Jim 2010a; Lo and Jim 2010b), revealed that air purification was considered to be one of the most important ecosystem services. In the research of Tyrväinen (2001), the benefits related to nature were rated as most important. The presence of biodiversity was perceived to be the most important green-space service in the research of Vihervaara et al. (2012) and Izaskun et al. (2013). The differing focus on ecosystem services may indicate that respodents from various cultural contexts hold varying perceptions.

In this study, it was notable that the importance of noise reduction, wind protection, economic value, neighbor-social interaction and water-soil conservation were ranked at the bottom of the importance hierarchy. Similarly, property values, neighbor-social interaction, noise abatement and soil erosion prevention were ascrbed the least importance in another Chinese city - Hong Kong (Lo and Jim 2011). Noise abatement and economic value were considered the least important in a study by Tyrväinen (2001), while economic value and the benefits related to environment quality such as control of wind and stormwater were ranked low in the research of Lorenzo (2000). These results may indicate that respondents were not aware of the importance of these indirect benefits derived from green spaces.

Several factors could have jointly contributed to the discrepancies of repondents' perceptions of ecocystem services in Xi'an city. Firstly, local enviromental conditions inevitably influence the perception of green spaces. For example, shading was ranked as the most important service in many countries, possibly due to the strong sunshine in summer, but not in Nordic countires like Finland (Tyrväinen et al. 2007), where summers are not so hot and sunshine is welcomed. Air quality improvement was not considered as a very important service like in other countries, although environmental problems are more acute in Chinese cities, possibly due to limited abatement of air pollution provided by green spaces (Nowak et al. 2006), in addition to a relatively low percentage area of green spaces, and an overload of exhaust fumes and other air pollutions in Xi'an. Moreover, in the predominantly high-rise city, the wind protection functions of urban green spaces are limited in most places.

Secondly, urban living is superior to living in rural areas in the perception of most Chinese people (Chen and Pang 2013; Li 2013). Urban areas usually provide more job opportunities, higher incomes, better living accommodation such as convenient transportation, more hospitals and schools (Chen and Pang 2013; Li 2013). Benefits related to nature are therefore not considered as important as those that bring direct material improvement to living conditions.

Thirdly, this study found that the most important services were those related to personal comfort and recreation, which can be directly or easily percevied and are tangible. On the other hand, less conspicuous ecological services such as water-soil conservation received low importance ratings. Stormwater and wastewater is usually collected and managed through the urban sewage systems rather than green spaces (Lou 2003). Therefore, citizens were mostly ignorant of the fact that green spaces also have an effect on water-soil conservation. In addition, in Chinese cities, green spaces seldom contribute economically improtant plants such as timber and fruits. This is perhaps unsurprising since traditionally, green spaces were understood as places of recreation and aesthetics (Lou 2003). Their economic value was underestimated mainly due to the lack of understanding how green spaces affect the prices of the neighboring real-estate. The limited understanding of such benefits implies that the possession or lack of relevant knowledge could affect perceptions. Therefore, to improve the recognition of the ecosystem services provided by urban green spaces, appropriate information could be included in public education and publicity programs for communication through formal and informal channels (Costanza et al. 1997; Lewan and Söderqvist 2002).

6.7.3.2 The Influence of Socioeconomic Variables on Respondents' Perceptions of Ecosystem Services

This study found that there was no significant correlation between respondents' perceptions of urban green spaces and their socioeconomic backgrounds. However, there were considerable differences in their ranking of individual services. This widespread recognition of ecosystem services will hopefully help in the implementation of urban policies and planning projects that promote ecosystem services.

6.7.3.3 The Influence of Park Variables on Respondents' Perceptions of Ecosystem Services

Park area and vegetation structure significantly influenced the respondents' perceptions of ecosystem services of green spaces (see Table 6.15). Respondents from the small to medium and medium-sized parks (5-10 ha and 10-30 ha, respectively) tended to consider the ecosystem services of green spaces as more important. Moreover, respondents also perceived the ecosystem services as more important in the parks with relatively higher percentages of multi-layered vegetation, trees and mature trees, and medium percentages of evergreen species. Based on a defined piece of ground, abundant layers of vegetation increase the green biomass and hence benefit ecosystem services such as CO_2 sequestration, air humidiy and lower air temperature. Moreover, the muliti-layered structure helps block the wind and alleviate air pollution due to the resulting interruption of airflow and deposition of particulates. A higher cover of trees, and especially mature trees, can directly provide shading by their large canopy. These vegetation characteristics, which determine ecosystem services, were likely considered as important simply because they can be perceived directly by the respondents.

6.7.4 Discussion of the Respondents' Assessments of Green Spaces

6.7.4.1 Comparison of Respondents' Assessments with Similar Studies

The results of assessments both at the city- and the park level indicated that the satisfaction of Xi'an's citizens with the quality of urban green spaces still needed to be improved. Generally, no more than 57.2% of the respondents assessed the entirety of green spaces as positive or very positive (Table 6.18). In a study from Porto and Lisbon, Portugal, a similar ratio of 61% and 62% of respondents were satisfied with the cities' green spaces, respectively (Madureira et al. 2015).

Among all the 20 assessment aspects, only 5 were assessed as positive or very positive by over half of respondents in the often-used urban parks. These included vegetation coverage, microclimate, overall assessment, cleanliness and scenic beauty (Table 6.18 and Figure 6.3). The study of Qin et al. (2013) also found that overall satisfaction with green spaces is higher than the satisfaction with specific parks. Among the specific aspects, pleasant landscape, visual elements, proximity to water and peaceful spaces were rated as the primary factors of satisfaction by park users in Ankara (Oguz 2000). In Finland, opportunity for activities, beautiful landscapes and freedom were the top three reasons for positive assessment (Tyrväinen et al. 2007). In Guangzhou, vegetation conditions, vegetation cover ratio and air quality were assessed very positively (Shan 2009). In general, the vegetation coverage and scenery were much more satisfactory in the above studies. The observation that items related to vegetation meet the demands of more respondents regarding use and aesthetics may indicate that the vegetation cover, condition and scenery have been paid more attention and enjoyed good development in green spaces. In fact, according to the field observation, most of the 22 investigated parks had over 50% of vegetation (see

Table 6.1). The high cover of vegetation can be viewed as the proximal reason for the respondents' satisfaction with vegetation cover.

Water quality and area, air quality, the number of sports facilities and the number of wild animals were rated the lowest, which may be attributed to the small size, insufficient management and heavy use of green spaces in China. It was notable that the neutral assessments accounted for relatively higher percentages, reaching even 50% for some aspects such as ecological functions at city level, as well as air quality and location of resting facilities at park level (Tables 6.18 and 6.19). In fact, the turbidity of water, especially of man-made lakes, can be seen directly in many parks as a deficiency of cleanliness. The improvement for air and water quality often goes beyond the department of urban green spaces and requires effective coordination mechanisms with other government departments e.g. the department of environmental protection.

6.7.4.2 The Influence of Socioeconomic Variables on Respondents' Assessments

Perhaps unsurprisingly, the respondents' family status influenced their assessments of the functions and facilities designed for children. For example, respondents living with children assessed playgrounds more positively but air quality more negatively than their childless peers. These findings may imply that respondents living with children are concerned with the quality of green spaces primarily from the perspective of children. Children are the main users of playgrounds, and park designers should consider their specific use by children in order to satisfy their parents. The reduced satisfaction with air quality from respondents who have children may indicate that they have higher requirements for air quality. This may be due to the effect of air pollution on children, who possibly have more pollution-related health problems due to their still underdeveloped organs.

By comparison, in the study of Qin et al. (2013), young and middle-aged respondents were more satisfied with the overall green spaces than the elderly (Qin et al. 2013). In a study by Shan (2009), marital status played a significant role in the assessment of urban green spaces - married respondents made consistently more positive assessments than singles in all aspects. Taken together, these findings demonstrate that the respondents' assessments are easily influenced by their socioeconomic status, though the concrete influences differ between social contexts.

6.7.4.3 The Influence of Park Variables on Respondents' Assessments

Considering the influence of the parks' characteristics, older parks located within the second ring road, and those with areas of 10-30 ha and 0-5 ha received relatively higher positive assessments from respondents (see Table 6.20). The results therefore revealed that, from the perspectives of respondents, not only do the bigger parks perform well in terms of the provision of ecosystem services, but the smaller parks were also able to provide satisfactory ecosystem services. Similar research in Guangzhou showed that municipal parks were assessed highly while small gardens were largely neglected (Shan and Yu 2014).

Moreover, the parks with medium cover of multi-layered vegetation and evergreens, as well as those with higher cover of trees but lower cover of mature trees, were assessed more positively than other types. These findings were in agreement with research conducted in Guangzhou, where park users presented more positive assessments in municipal parks, which had better vegetation conditions than the district parks (Shan and Yu 2014). In research from Iran, respondents most highly assessed the scenery that was characterized by 20-60% of multi-level plantings, mainly including various trees (Aminzadeh and Ghorashi 2007). In this study, the results highlighted the fact that increased tree cover can help increase the satisfaction with parks. Trees can directly benefit the quality of scenery in green spaces as its integral components. Although tree cover cannot change the conditions of sporting facilities, resting facilities and playgrounds, their contribution to environmental improvement of parks may indirectly improve the perception of the overall green space and hence also of the other items of ecosystem and leisure services. For example, respondents may feel more comfortable when they have an opportunity to rest in the shade of trees, and they may prefer to do sports or participate in activities in green spaces with abundant trees. Moreover, the parks with medium cover of multi-layered vegetation, mature trees and evergreen trees may provide balanced shading, sporting spaces, beautiful scenery and temperature regulation due to the larger canopies, relatively open spaces and scenery, stronger transpiration and shielding of pollutants, and therefore, easily received positive assessments from respondents.

Generally, respondents' assessments of the majority of the above-mentioned aspects of green spaces were less positive. Moreover, positive assessments were more common in the parks with a higher cover of trees but lower cover of mature trees and medium cover of multi-layered vegetation and evergreens. The modest satisfaction with urban green spaces indicates that there is a noticeable gap between current status of green spaces and citizens' expectations. This implies the necessity for substantial improvement of urban green spaces in Xi'an. Despite the lack of analogous local studies to compare, the findings from this investigation of 22 urban parks provide some important guidelines for the improvement and development of green spaces in the future.

6.7.5 Discussion of Respondents' Demands for Green Spaces

6.7.5.1 Comparison of Respondents' Demands with Similar Studies

Generally, the respondents in this study voiced active demands for the referred items provided by green spaces. More shade, more opportunities to observe nature, more flowers and better management were the primary demands for urban green spaces from respondents in Xi'an city (Figure 6.4). Some of the respondents indicated that they needed more recreational opportunities, e.g. more facilities for sports and exercise, more play areas for children and more resting facilities, but less wind protection and cafes or restaurants (Figure 6.4). In spite of their different cultural contexts, people share some common desires for features of urban green spaces. For example, a study from Hong Kong indicated that the residents' wanted more greenery, and especially trees (Lo and Jim 2011). A survey in East midlands, UK showed that the respondents most sought green spaces with a natural appearance (Bell et al. 2004). In Sapporo, Japan, a survey suggested that flowers were the most preferred among possible elements for the space beneath street trees (Todorova et al. 2004).

Usually, expectations of urban green spaces are predominantly associated with natural features such as natural appearance, trees, water, flowers and grasses (Yuen et al. 1999). The need for nature contact may be prompted by the acute shortage of urban greenery and the highly regimented and manicured design of traditional urban green spaces. In practice, the predominant stereotypic and old-fashioned park design fails to meet the users' demands and is detached from the different demands among age groups, vocations and incomes. For example, Access to managed lawns and vegetated areas is prohibited in the majority of urban parks in Xi'an. This rule constrains the users' contact with nature and leads to unmet demands.

6.7.5.2 The Influence of Socioeconomic Variables on Respondents' Demands

In this study, the respondents' demands varied with different park age and location. Respondents from different age- and vocational groups presented different demands. The elderly demanded more quiet spaces, larger play areas for children, more resting facilities and less cafes and restaurants than the other age groups. The demands for play areas and resting facilities may be related to the care for children. It can be understood that elderly demanded more play areas for children because it is a widespread social phenomenon in China that the elderly look after their grandchildren. With aging, the need for quiet and resting facilities increases due to decreased vigor. Similarly, in the study from Hong Kong, age influenced the residents' anticipations, and older users needed more seats in green spaces (Lo and Jim 2011). In Guangzhou, the married more strongly preferred naturalness, facilities and accessibility than singles (Shan 2009). Bringing children to green spaces for play usually constitutes a predominant reason for the visits of families with children, and meeting the children's demands is their primary consideration.

6.7.5.3 The Influence of Park Variables on Respondents' Demands

Respondents from the older parks voiced a stronger need for improving many kinds of ecosystem services locally. This result may indicate that the facilities and management of older parks are unsatisfactory due to their long history of use and their outdated design. Respondents in the parks with lower cover of multi-layered vegetation and evergreens usually wanted more shade, wind protection, sporting facilities and water bodies. By contrast, the respondents from the parks with higher cover of trees and mature trees wanted better management, more quiet places and more flowers. This shows that respondents' demands varied with different park characteristics, and their needs are thus connected with their direct visual and use experiences in the parks. These subjective perspectives can work well in most cases. For example, in the parks with higher cover of trees, there were more demands for flowers, while in the parks with 0-25% of mature trees there were more demands for shading because the lower cover of mature trees provided less shading.

Conversely, the results also suggest that the urban environments may influence the citizens' perspectives and interactions with urban nature. Hence, it would be reasonable to establish corresponding public policies. However, green space planners and managers often hold different views than users (Burgess 1988; Coles and Bussey

2000). The traditional dominance of professional inputs tends to neglect users' views and demands. Public participation and engagement in green space design remain ineffective. This study demonstrates again that the public's views and demands should be considered and adopted in the process of green space planning and development. Survey-based communication between the public / park users and park managers / planners is an effective method to fill the gaps between provisions and demands, and thus to avoid the construction of underused or unwanted green spaces.

7 Assessment of Ecosystem Services Generated by Urban Parks in Xi’an

7.1 Regulating Services of Urban Parks in Xi’an

7.1.1 Indicator Ratings of Regulating Services of Urban Parks in Xi’an

The vegetation structures and types discussed in section 2.3.2 were used as indicators to assess the regulating services of green spaces in this study. The first four indicators revealed the effects of microclimate regulation. In addition to these, the cover of evergreen species was supplemented to better assess the green spaces’ effects on air pollution.

Vegetation and Water (1.1)

All of the 22 investigated parks in Xi’an were covered with over 50% of vegetation and water, with thirteen having over 75% (see Figure 7.1). The highest proportion of total vegetation and water was 92.1% in Xin Ji Yuan Park, and the lowest was 62.6% in Children’s Park (see Figure 7.1). Therefore, all the parks were ranked as having medium or large covers of vegetation and water.

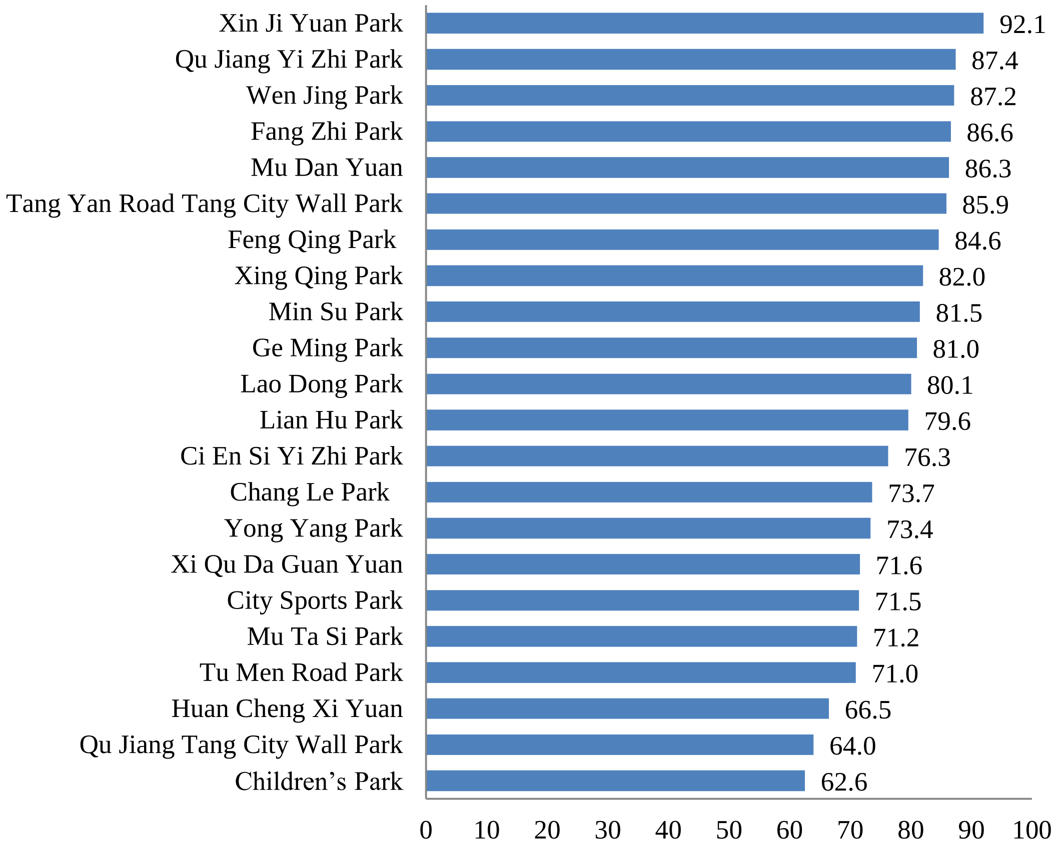

Figure 7.1 Cover ratio of vegetation and water in the 22 investigated parks in Xi’an

Multi-layered Vegetation (1.2)

Multi-layered vegetation structures, having at least two layers, were found in all of the 22 investigated parks (see Figure 7.2). Moreover, the vegetated areas in over half of the parks were covered with over 75% of multi-layered vegetation. Especially in Mu Ta Si Park, Mu Dan Yuan and Tu Men Road Park, the relative percentages of multi-layered vegetation reached as high as 96.3%, 94.6% and 94.4%, respectively (see Figure 7.2). According to the rating rules, it can be seen that these parks attained the high rank (≥76%) (see Figure 7.2). Six parks were in the medium rank (51-75%), with percentage areas of multi-layered vegetation ranging from 52.5% in Feng Qing Park to 73.1% in Ge Ming Park (see Figure 7.2). Five parks were in the low rank (26-50%).

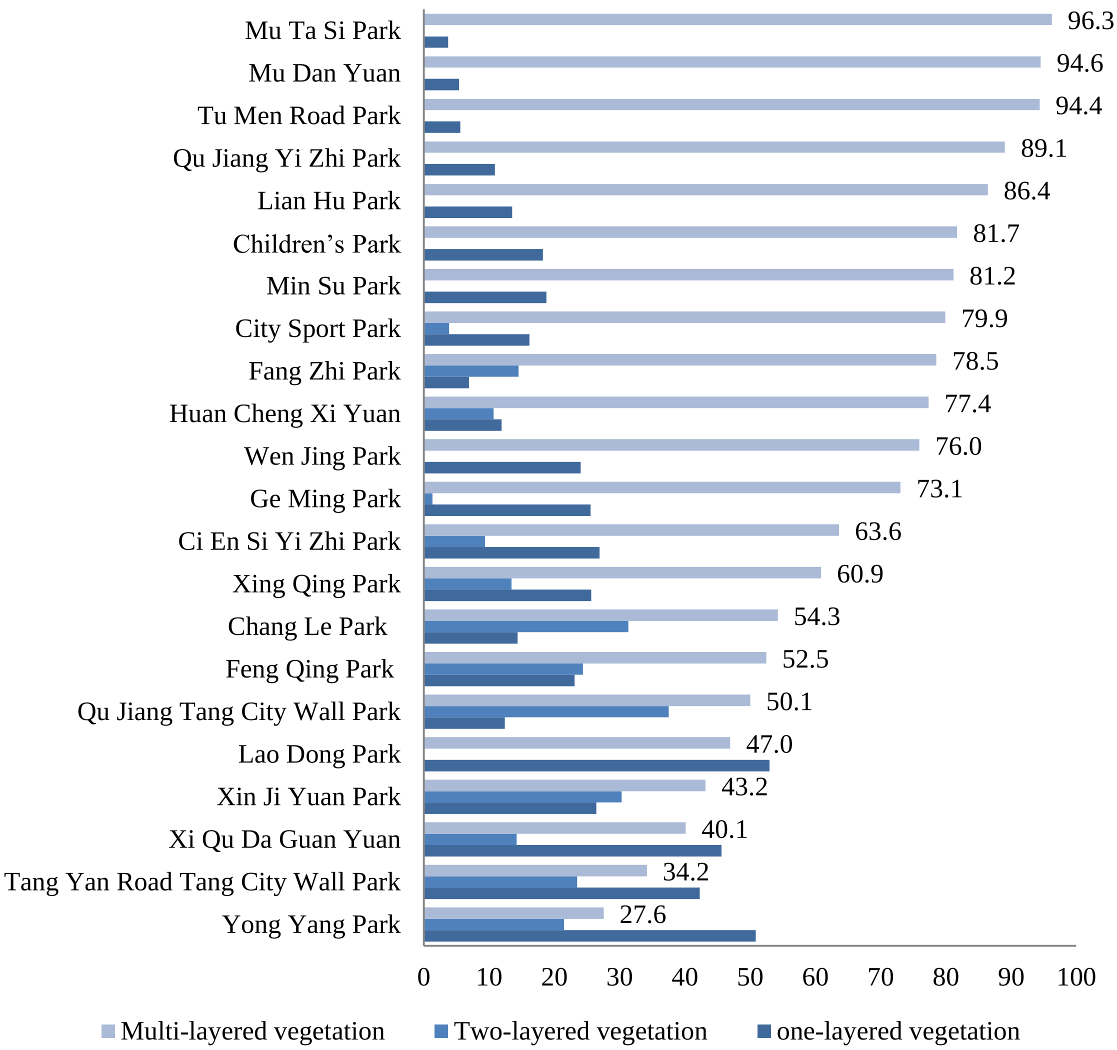

Figure 7.2 Relative proportions of vegetation layers in the 22 investigated parks in Xi'an.

Tree Cover (1.3)

Tree cover ranged from 26% to 92.2% in the 22 investigated parks, with twelve parks having over 50% of tree cover. Six parks had over 75% of tree crown coverage in their vegetated areas, with the percentage areas ranging from 75.5% in Ci En Si Yi

Zhi Park to 79.9% in Ge Ming Park, and rising to the highest percentage of 92.2% in Lao Dong Park. These parks were hence rated as having the high rank (see Figure 7.3). Additionally, six parks had tree covers between 50% and 75%, with the proportion ranging from 51.9% in Mu Ta Si Park to 74.4% in Min Su Park (see Figure 7.3). Therefore, these six parks were rated as having the medium rank. The other ten parks were rated in the low rank since their relative proportions of trees were in the rage of 26-50% (see Figure 7.3).

Mature Tree Cover (1.4)

The relative proportion of mature trees was low in all of the investigated parks, and the vegetation cover comprised over 50% mature trees in only four. Chang Le Park had the highest relative coverage of mature trees at 66.5%, and therefore reached the medium rank of regulating impact (see Figure 7.4). Two parks had relative mature tree coverages between 25% and 50%. One was Xing Qing Park (35.8%) and the other was Children's Park (46%) (see Figure 7.4). The remaining 16 parks all ranked very low, whereby the percentage area of six parks ranged from 21.6% to 24.9%, while eight parks had no cover of mature trees at all (see Figure 7.4).

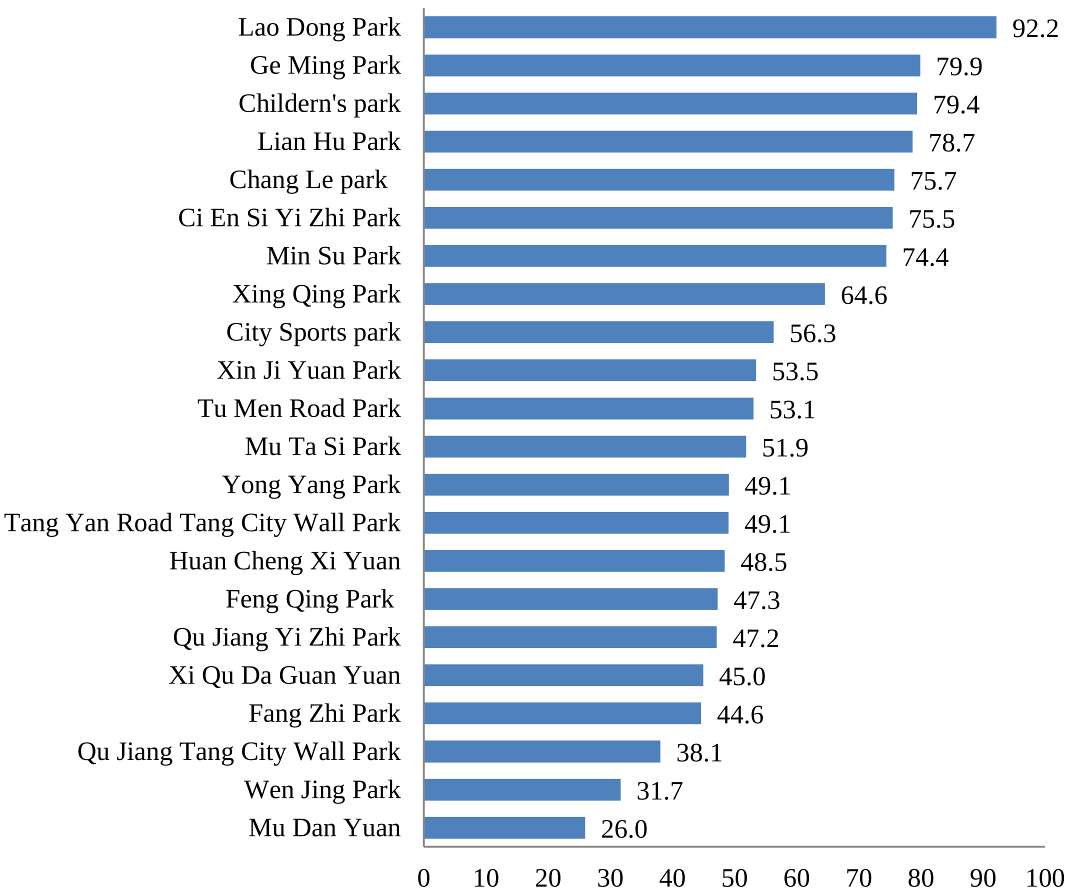

Figure 7.3 Relative proportions of tree cover in the 22 investigated parks in Xi'an.

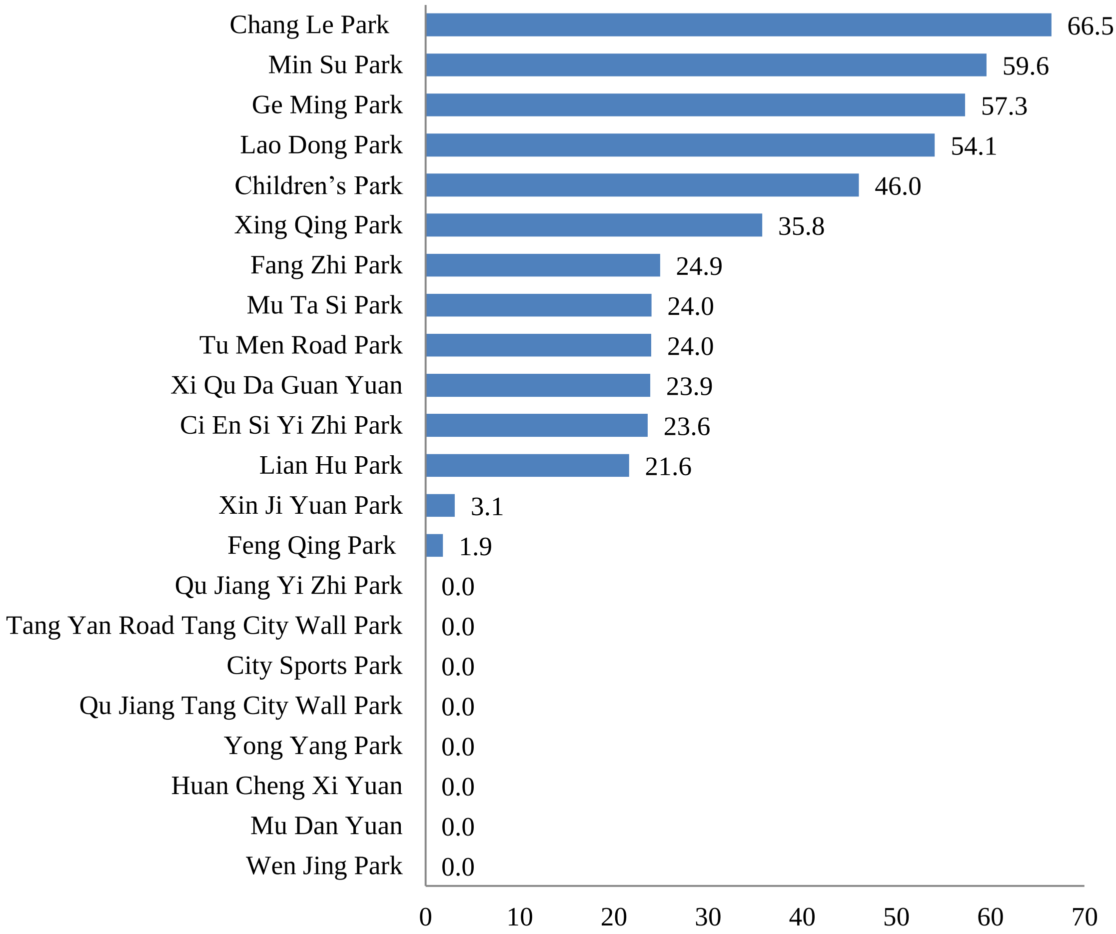

Figure 7.4 Relative proportions of mature trees in the 22 investigated parks in Xi'an.

Evergreen Species Cover (1.5)

All the investigated parks were designed to contain evergreen woody plants, including many kinds of trees and shrubs. According to the rating rules, two parks were ranked as having a high regulating level due to their evergreen coverage, which was in excess of 75%. The coverage reached 80.6% in Min Su Park and 87.0% in Chang Le Park (see Figure 7.5). Accordingly, ten parks were ranked as medium impact (51-75%), with relative evergreen covers ranging from 52.2% in Ci En Si Yi Zhi Park to 70.9% in Tu Men Road Park (see Figure 7.5). Nine parks were ranked as low due to their 25-50% of evergreen cover. Especially, Tang Yan Road Tang City Wall Park had only 13.3% of evergreen species' cover and therefore was ranked as having a very low impact on the regulation of air pollutants (see Figure 7.5).

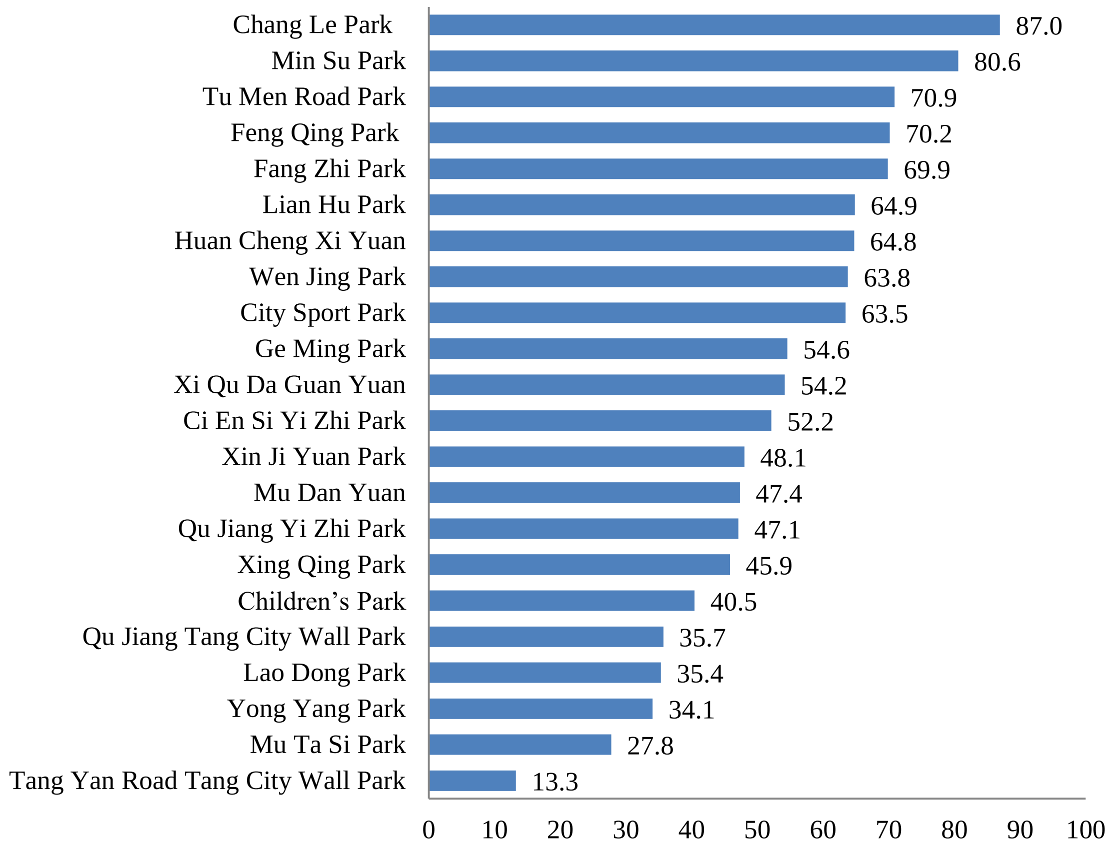

Figure 7.5 Relative proportions of evergreen species in the 22 investigated parks in Xi’an.

7.1.2 Assessment of Integrated Indicators of Regulating Services of Urban Parks in Xi’an

In this study, regulating services were mainly investigated in terms of microclimate regulation and air pollution improvement. The values of regulating services of the 22 investigated parks were assessed based on aggregations of the specific assessment indicators (see the detailed method in Section 3.2.2.4). Overall, four parks had high values of air quality regulation, fifteen parks had medium values, and three had low values (see Table 7.1). With the exception of Lian Hu Park, the three other high-value parks - Min Su Park, Ge Ming Park and Chang Le Park, all had medium and high impacts on all the assessed indicators. The low valued parks - Yong Yang Park, Qu Jiang Tang City Wall Park and Tang Yan Road Tang City Wall Park had low values of mature tree cover and evergreen species cover.

Table 7.1 Assessment of integrated indicators of regulating services

Score of assessed indicators \ Park	Children's Park	Tu Men Road Park	Fang Zhi Park	Ci En Si Yi Zhi Park	Xi Qu Da Guan Yuan	Lian Hu Park	Min Su Park	Xin Ji Yuan Park	Wen Jing Park	Mu Ta Si Park	Mu Dan Yuan	Lao Dong Park	Ge Ming Park	Huan Cheng Xi Yuan	Yong Yang Park	Chang Le Park	Feng Qing Park	Qu Jiang Tang City Wall Park	City Sports Park	Tang Yan Road Tang City Wall Park	Xing Qing Park	Qu Jiang Yi Zhi Park
Score of 1.1	3	3	4	4	3	4	4	4	4	3	4	4	4	3	3	3	4	3	3	4	4	4
Score of 1.2	4	4	4	3	2	4	4	2	4	4	4	2	3	4	2	3	3	2	4	2	3	4
Score of 1.3	4	3	2	4	2	4	3	3	2	3	2	4	4	2	2	4	2	2	3	2	3	2
Score of 1.4	2	1	1	1	1	1	3	1	1	1	1	3	3	1	1	3	1	1	1	1	2	1
Total score for microclimate regulation	13	11	11	12	8	13	14	10	11	11	11	13	14	10	8	13	10	8	11	9	12	11
Assessment of microclimate services	H	M	M	M	L	H	H	M	M	M	M	H	H	M	L	H	M	L	M	M	M	M
Score of 1.5	2	3	3	3	3	3	4	2	3	2	2	2	3	3	2	4	3	2	3	1	2	2
Total score for air pollution removal	15	14	14	15	11	16	18	12	14	13	13	15	17	13	10	17	13	10	14	10	14	13
Final assessment of air pollution removal	M	M	M	M	M	H	H	M	M	M	M	M	H	M	L	H	M	L	M	L	M	M

H: high; M: medium; L: low; VL: very low

However, the value of the individual parks' microclimate regulation showed some differences (see Table 7.1). According to the rating rules, among all the parks, six had high values of microclimate regulation, compared to thirteen with medium values and three with low values. Generally, the parks provided similar regulation of microclimate and air quality. Nevertheless, some cases were exceptions. For example, Xi Qu Da Guan Yuan had a low value of microclimate regulation but medium value of air pollution reduction, and Tang Yan Road Tang City Wall Park had a medium value of microclimate regulation but a low value of air pollution reduction. Children's Park and Lao Dong Park showed a high value of microclimate regulation, but provided only a medium value of air pollution reduction.

Considering the varying park area, age and location, the relationship between these variables and air pollution removal / microclimate regulation were analyzed using the Chi-squared test. Somewhat surprisingly, it was found that there were no significant relationships between the value of air pollution removal and park variables. However, the results showed that the majority of the parks with high values of regulating services were small to medium-sized parks, which were located within the second ring road and built prior to the 1990s, such as Lian Hu Park and Ge Ming Park. Using a similar analysis, it was revealed that microclimate regulation of the parks showed significant relationships with park variables. Of the six high-value parks regarding microclimate regulation, five were built prior to the year 1990 ($X^2 = 10.358$, $p = 0.006$). Furthermore, five were located within the second ring road ($X^2 = 6.229$, $p = 0.044$).

7.1.3 Citizens' Assessments of Regulating Services of Urban Parks in Xi'an

In accordance with the descriptions set out in Chapter 6 (see Table 6.18), 70.8% of the respondents assessed the overall microclimate regulation of the parks as "good" or "excellent", compared to 22.7% who stated the same for air quality. According to the rating rules, the entirety of parks as a whole was considered to have a medium value of microclimate regulation, but a low value of air quality improvement.

The associations between respondents' assessments of microclimate / air quality and socioeconomic variables were analyzed using the Chi-squared test. Children were a factor which influenced the respondents' assessment of air quality ($X^2 = 12.2946$, $p = 0.015$), so that more respondents who had no children positively assessed the air quality (28.22% versus 18.87%).

Considering park characteristics, it was found that the park age and location had significant relationships with respondents' assessments of microclimate using the Chi-squared tests. In the older parks, 78.7% of respondents positively assessed the microclimate ($X^2 = 7.939$, $p = 0.047$), and this positive assessment was 11.6% higher than in the newer parks. 72.3% of respondents from the parks located inside the second ring road considered the microclimate to be satisfactory, compared to 64.1% from parks located inside the third ring road (X^2 = 13.201, p = 0.004).

Using the same methods to analyze the associations between vegetation characteristics and respondents' assessments of microclimate and air quality, it was found that multi-layered vegetation and evergreen species had a significant influence. 81.1% and 72.5% of respondents from the parks with 26-50% and 51-75% of multi-layered vegetation positively assessed the local microclimate (X^2 = 19.560, p = 0.003). However, the positive assessment of air quality was dramatically lower. The highest percentage of positive assessments reached only 34.3% in the parks with 51-75% of multi-layered vegetation (X^2 = 21.885, p = 0.005). Moreover, there was a highly statistically significant association between evergreen cover and microclimate assessment (X^2 = 22.925, p = 0.006). More respondents (78.0% and 69.8%) in the parks with relatively lower cover of evergreens (26-50% and 0-25%, respectively) positively assessed the microclimate than their peers in other parks.

7.2 Recreational Services of Urban Parks in Xi'an

7.2.1 Citizens' Assessments of Recreational Services of Urban Parks in Xi'an

As described in section 6.5, 46.7% of the respondents assessed the overall recreational services of all the green spaces in Xi'an city as either "excellent" or "good" (see Table 6.16), which means that less than half of the assessments were positive. According to the rating rules, the entirety of green spaces was thus considered to have low value of recreational services. For the individual parks, the respondents' assessments of recreational services were represented by the indicators of scenic beauty (2.1), sporting facilities (2.2-2.4), resting facilities (2.5-2.7) and playgrounds (2.8-2.10).

Scenic Beauty (2.1)

Even though it is one of the most important reasons for citizens to visit green spaces, scenic beauty received only 49.3% of "excellent" or "good" assessments from respondents in this study (see Table 6.18). Moreover, 41.1% of respondents deemed the scenery to be fair in their often-visited parks. According to the rating rules, the parks as a whole were therefore considered to have a low value of scenic beauty.

Sporting Facilities (2.2-2.4)

Summing the assessments of sporting facilities provided by parks, 27.6% of respondents considered the number of sporting facilities to be sufficient in their daily-used green spaces (see Table 6.18). Meanwhile, 40.1% and 38.1% considered the location and maintenance of sporting facilities to be suitable (see Table 6.18). Although more respondents were satisfied with the location and maintenance, than with the number of sporting facilities, the percentage of positive assessments was less than half. According to the rating rules, the parks had a low value regarding their provision of sporting facilities.

Resting Facilities (2.5-2.7)
Overall, positive assessments reached only 29.2% for the number of resting facilities, compared to 38.6% and 44.7% for the location and maintenance of resting facilities (see Table 6.18). According to the rating rules, the parks as a whole were considered to have a low value of resting facilities.

Playgrounds (2.8-2.10)
Overall, 40.9% of respondents thought that there were adequate areas of playgrounds in their often-used green spaces (see Table 6.18), 42.0% and 49.6% of which felt that the location and maintenance of playgrounds was suitable, respectively (see Table 6.18). Generally, less than 50% of the respondents positively assessed the three items pertaining to playgrounds. Therefore, according to the rating rules, the parks were considered to have low values regarding their provision of playgrounds.

7.2.2 Integrated Assessment of Recreational Services of Urban parks in Xi'an

The values of recreational services of urban parks were summarized by adding together all the impact scores of the ten discussed indicators. When the 22 investigated parks were taken as a whole, the final assessment was low (see Table 7.2). For the individual parks, the assessments did not vary by different park groups and vegetation structures. Taking the variable of park area as an example, parks in all the different area groups had low values for total recreational services (see Table 7.2).

Nevertheless, the Chi-squared test revealed that some park variables showed significant relationships with some specific items of recreational services. For example, park area influenced the respondents' assessment of scenery ($X^2 = 11.167$, $p = 0.011$). Respondents tended to positively assess the scenic beauty in the parks with areas of 10-30 and 0-5 ha. In addition, scenery in the parks built prior to the 1990s satisfied more respondents than the scenery in parks built after the 1990s (52.8% versus 47.9%).

Considering the influence of vegetation structure, a twice higher percentage of respondents (31%) positively assessed the scenery in parks with 76-100% of vegetation and water ($X^2 = 9.576$, $p = 0.048$). The positive assessments of scenery were also increased by the increasing coverage of multi-layered vegetation ($X^2 = 72.816$, $p < 0.001$). However, this positive assessment decreased with the increased cover of trees and mature trees. The highest positive assessment was recorded in the parks with 26-50% of trees and 0-25% of mature trees ($X^2 = 18.546$, $p = 0.017$, $X^2 = 39.718$, $p < 0.001$). Parks with a relatively high cover (51-75%) of evergreens received more positive assessments than the others ($X^2 = 69.771$, $p < 0.001$).

Respondents' assessments of the number and location of sporting facilities varied significantly by park area. Satisfaction with the location of sporting facilities reached 60.5% in parks with areas of 0-5 ha, followed by 43.6% and 40.3% in parks with areas of 10-30 ha and 30-60 ha, respectively ($X^2 = 12.783$, $p = 0.005$). However, satisfaction with the number of sporting facilities was 41.9% in the parks with areas of 0-5 ha and only 9% in the parks with areas of 5-10 ha ($X^2 = 27.403$, $p < 0.001$). Moreover, in the parks built prior to the 1990s, 48% of respondents were satisfied with the location of sporting facilities, compared to 37% in newer parks ($X^2 = 4.347$, $p = 0.037$).

The cover of vegetation, water and evergreens had a significant influence on the number, location and maintenance of sporting facilities. The parks with 75-100% of vegetation and water, and 51-75% of evergreens, received more positive assessments than the other parks. Interestingly, the cover of multi-layered vegetation, trees and mature trees also influenced some items related to sporting facilities. Parks with 0-25% of mature trees were considered more satisfactory regarding the number and maintenance of sporting facilities, whereas the location and maintenance was deemed better in the parks with 0-25% of trees.

In addition, park area, age and location had a significant relationship with the respondents' assessments of resting facilities. The smaller, older parks located inside the second ring road received slightly more positive assessments, while parks with increasing cover of multi-layered vegetation received higher positive assessments of the maintenance of resting facilities. Interestingly, the parks with increasing tree cover and mature tree cover had a decreased satisfaction rating of the number and location of resting facilities. However, parks with 76-100% of vegetation and water were more positively assessed regarding the number, location and maintenance of resting facilities.

Lastly, the parks with areas of less than 30 ha received more positive assessments of the number of playgrounds. The highest percentage of satisfaction was 59.0% for the parks with areas of 10-30 ha ($X^2 = 18.163$, $p < 0.001$). Meanwhile, 55.1% and 53.5% of positive assessments of the location of playgrounds came from parks with areas of 10-30 ha and 0-5 ha, respectively ($X^2 = 11.859$, $p = 0.008$). The percentage of positive assessments decreased for the other parks.

Park age and location also influenced the respondents' assessments of the number of playgrounds. In the parks built prior to the 1990s, 51.2% of respondents declared that they are satisfied with the number of playgrounds, compared to only 36.7% in newer parks ($X^2 = 7.623$, $p = 0.006$). Similarly, 54.4% of satisfaction was recorded in parks located within the second ring road, which was higher than for parks located within the third ring road ($X^2 = 23.343$, $p < 0.001$).

Considering the vegetation structure, it was found that the parks with 76-100% of vegetation and water were positively assessed regarding the number and location of playgrounds. Additionally, a reduced cover of trees raised the respondents' positive assessments of the number, location and maintenance of playgrounds.

Table 7.2 Integrated assessment of recreational services by park area

	Often-used parks as a whole (22)	Park area (number of parks)			
		0-5 ha (5)	5-10 ha (8)	10-30 ha (4)	30-60 ha (5)
Score of 2.1	2	1	1	1	1
Score of 2.2	2	1	2	1	1
Score of 2.3	2	1	1	1	1
Score of 2.4	2	2	2	2	3
Score of 2.5	2	1	1	1	1
Score of 2.6	2	2	1	1	1
Score of 2.7	2	1	1	1	1
Score of 2.8	2	1	1	1	1
Score of 2.9	2	1	1	1	1
Score of 2.10	2	1	1	1	1
Total score of recreational services	20	12	12	11	12
Final assessments of recreational services	L	L	L	L	L

H: high; M: medium; L: low; VL: very low

7.3 Discussion

7.3.1 The Influence of Park Variables on the Assessment of Regulating Services

The majority parks investigated in this study had medium to high percentages of vegetation and multi-layered vegetation, but low percentages of mature trees. Consequently, they had a medium impact on the regulation of microclimate and air quality (see Table 7.1). Nevertheless, the percentage of trees and evergreens varied obviously among the parks, and four parks provided a high value of air quality regulation. By comparison, more parks (six) provided a high value regarding the regulation of microclimate. Three parks showed very limited values of air quality removal / microclimate regulation.

Generally, the older parks with 5-10 ha of area, which were located within the second ring road, usually provided high values of microclimate regulation and air pollution removal. However, similar studies of Chang (2007) and Andrade and Vieira (2007) showed that bigger parks had higher impacts on temperature regulation. In their studies, air temperature was lower on average in larger parks than in smaller ones (Andrade and Vieira 2007; Chi-Ru Chang et al. 2007). Notwithstanding, it is impossible to establish an accurate linear relationship between the size of parks and the temperature variation associated with them (Andrade and Vieira 2007; Chi-Ru Chang et al. 2007), because the temperature change also highly depends on the structure of vegetation, the topography and the characteristics of the parks' surroundings (Andrade and Vieira 2007; Givoni 1991b).It should also be noted that the range of the effect of parks on the climatic conditions within the surrounding built-up areas is rather limited, even in the case of very large ones, or areas downwind of the parks (Givoni 1991a). However, nearly all the larger parks investigated in this study were built after the 1990s. These modern parks provided open lawns, and their trees had not developed their optimal crowns yet because of their young age. The presence of lawns and lower cover of trees, and especially mature trees, in these parks lead to a vegetation structure which cannot provide a high value of microclimate regulation.

The influence of park age was essentially mediated by the vegetation structure, since it is self-evident that the relative proportion of mature trees is determined by the age of the parks. All the parks in this study with medium proportions of mature trees were older parks built prior to the 1990s, such as Children's Park, Lao Dong Park and Ge

Ming Park (see Tables 3.1 and Figure 7.4). Trees typically require 20-30 years to grow to a fully functional size. As such, older parks usually have more large trees, thereby enhancing regulating services. Similarly, an investigation of park trees in Bangalore, India, showed that park history had an impact on the distribution of trees (Henrique Andrade and Vieira, 2007). Unsurprisingly, the size of trees (diameter at breast height and height) in older parks (built in the 1970s) was significantly greater than of those established in more recent years (built in 1990s). Therefore, older parks are likely to provide stronger air quality and air temperature regulation than newer parks.

Accordingly, it would follow that the parks located within the second ring road, near the city center, very likely provided high values of regulating services (see Table 7.2). In reality, this relationship was not mediated by the distance to the city center, but rather by park age, and hence vegetation structure types. Accompanying urbanization, Xi'an city continued to expand outwards. Therefore, parks located in or near the core city areas were constructed prior to the more distant parks (e.g. they were built before the 1990s as opposed to later), and thus had sufficient time to form a large canopy cover of trees and mature trees.

The value of microclimate regulation is the basis of the assessment of air pollution abatement. The majority of parks showed correlating values of microclimate regulation and air pollution removal. However, there were still some differences between them, which were derived from the differences in the cover of evergreen species (see Table 7.1). For example, Xi Qu Da Guan Yuan showed a low value of microclimate regulation, but had a medium value of air pollution removal, due to the medium cover of evergreen species. Children's Park and Lao Dong Park showed high values of microclimate regulation but medium values of air pollution removal, because these two parks had a low proportion of evergreen species. The results thus revealed that evergreen species are an important factor which influences air purification. It therefore follows that if there is a lower cover of evergreen species, the parks that provide medium to high values of microclimate regulations will provide lower values of air pollution removal. A balanced proportion of evergreen species is thus a useful method to promote the reduction of air pollution.

From the perspective of the respondents, it can be seen that more individuals positively assessed microclimate than air quality. As described in the theoretical chapter, microclimate regulation in this study mainly focused on the decreased air- and surface temperature in summer. The removal of air pollution included the absorption, decomposition and settlement of particulate and gaseous pollutions. In view of the severe levels of air pollution in Xi'an, which greatly exceed the norms prescribed by the World Health Organization (Chai et al. 2014), it is entirely possible that the majority of park visitors were not able to clearly perceive the air improvement induced by green spaces. This may be not only due to the small effect in light of the great amount of pollution, but also because many air pollutions cannot be observed directly. The respondents may thus primarily consider the limited improvement of air quality that is directly observable, such as the deficiency of fresh air everywhere, especially with consideration of children's health. Therefore, a majority assessed the air quality negatively. By contrast, most respondents can feel that the air is cooler in parks than in roadsides or in buildings without air conditioning.

From the respondents' viewpoint, older parks located in and near the city center and with relatively lower cover (26-50%) of multi-layered vegetation and evergreens had higher regulating services. This assessment was in agreement with the results of indicator assessment, and therefore revealed that the respondents can indeed perceive some ecosystem services, such as microclimate regulation. As for the influence of vegetation structure, the respondents may consider that the thermal comfort of parks is always connected to the shade of trees. Accordingly, the positive assessment of microclimate regulation increased with increased cover of trees and mature trees, though there were no significant associations between them. In fact, a majority of the 22 investigated parks had over 50% of tree cover. The relatively high cover of trees and the limited variations among parks may have prevented the respondents from perceiving the differences of microclimate regulation among parks. In addition, respondents likely could not perceive the microclimate benefits derived from increased multi-layered vegetation and evergreens, although a higher percentage of multi-layered vegetation will produce more biomass and higher transpiration, and hence provide measurably better temperature regulation (Armson et al. 2012).

Moreover, large shaded areas in summer are mainly provided by mature broadleaf trees (Armson et al. 2012). However, the number of evergreen species in the parks of Xi'an city is very limited, usually including a few types of trees and shrubs, such as species from the family Pinaceae, and broadleaf evergreens such as *M. grandiflora, Ligustrum lucidum, Photinia serrulata* and *Buxus sinica* (Xu and Zhang 2006; Zhao et al. 2004). The leaf forms and crown shapes of these evergreen species normally do not provide a large canopy. Shrubs cannot provide shading either. Therefore, the respondents may think that a large cover of evergreens does not contribute much to cooling.

In summary, indicator assessment system implies that vegetation structure is the key factor deciding the regulating services of parks. The highly valued parks usually had a higher cover of trees, and especially mature trees and evergreens. However, vegetation characteristics are very local and context-dependent. It is thus difficult to compare the results with studies from other countries. In addition, park age directly influenced the vegetation structure, since trees typically need a long time to form their optimal crown.

In this study, the value of regulating services was assessed without complicated procedures. While very practical, this kind of indicator assessment has some shortcomings. The types of vegetation structure that were used as indicators to assess the value of parks' regulating services concentrated on the cover, layering and composition of vegetation, but omitted further details. However, the regulating impacts of parks depends not only on the vegetation structure such as tree cover, plant density and length of in-leaf season, but also on the surrounding conditions such as built-up areas and concentration of pollutants (Nowak et al. 2006; Yin et al. 2011). Built-up areas generate warm and unstable air (Andrade and Vieira 2007), and hence require more transpiration from nearby parks to counteract their negative effects. Since pollution is caused mainly by traffic emissions and is attenuated with distance, parks that are located near major roads are exposed to more serious air pollutants due to heavier traffic flows (Yin et al. 2011).

In addition, this study attempted to explore the associations between park area / park age / park location and the provisions of regulating services. However, the locations of parks were only divided by the distance to the city center along the ring roads, so that the surrounding circumstances, such as the distance to main roads and heavy traffic, were not considered. In the future, the exploration of more detailed information should focus on the interactions between specific regulating services (e.g. cooling effects and reduction of air pollution) and park characteristics (e.g. the biomass structure in the parks and the surrounding land use of parks).

Lastly, the respondents' assessments can be used as evidence of the improvement of regulating services. However, among all of the 22 investigated parks, only six received more than twenty questionnaires (see Table 3.5). The small numbers of questionnaires at the individual park level thus limits the accuracy of the statistical analysis needed to evaluate the respondents' assessments.

7.3.2 Discussion of the Assessment of Recreational Services

7.3.2.1 Comparison of the Assessment of Recreational Services with Similar Studies

Generally, all of the 22 parks were considered to provide low values of recreational services as a whole. Among the specific items of recreational services, scenery was positively assessed by no more than half of the respondents in this study. By contrast, the study of Özgüner and Kendle (2006) noted that scenery of green spaces was positively assessed by the majority of respondents (more than 80%) at investigated sites in the UK. In Hong Kong, positive appraisals of scenic beauty in green spaces exceed 52.6% (Shan 2009). Comparisons therefore show that the positive assessment of scenery is lower in Xi'an than in other cities, including another Chinese city - Hong Kong. The scenery in the parks of Chinese cities is typically artificial (Qiu 2009). From the perspective of respondents' needs in this study (see Chapter 6.6), there were stronger desires for increased nature, peaceful atmosphere and shade in parks. Therefore, there is an urgent need to improve the scenery of parks in an effort to meet the citizens' requirements.

The positive assessments of the number of sporting- and resting facilities were relatively low. Similarly, Shan (2009) and Lo and Jim (2011) both found that resting and sporting facilities received relatively low positive assessments in Hong Kong. In fact, over half of the respondents considered sporting and resting facilities (e.g. seats and pavilions in green spaces) to be insufficient (Lo and Jim 2011; Shan 2009). These deficiencies reflect the inadequate per-capita share of urban green space areas compared to the high population densities in modern megacities. While park visitors tend to seek recreation (e.g. peace, relaxation, beauty and exercise) in the green spaces, the design of green spaces has not notably focused on fulfilling this requirement. Furthermore, there are insufficient numbers of playgrounds in the majority of parks and some parks have no special playgrounds for visitors (see Table 4.1). The playgrounds in the parks of Chinese cities are the main places that provide many kinds of entertainment facilities, such as carousels, Ferris wheels and miniature trains. These entertainment facilities are always based on charging a fee. However, park users can use any safe and open spaces to play games. This study suggests that sufficient and suitable resting and sporting facilities and playgrounds should be considered during the design process of urban parks to enhance the parks' use by citizens in their daily lives, though this is a difficult issue when faced with a huge population and a relative shortage of green spaces.

7.3.2.2 The Influence of Park Variables on the Assessment of Recreational Services

The small parks (0-5 ha) built prior to the 1990s and located inside the second ring road, with higher cover of vegetation, water and evergreens, but lower cover of trees and mature trees, typically elicited slightly positive responses on the specific items of recreational services. The older parks near the city core areas usually encompassed higher volumes of established sporting and resting facilities and playgrounds, compared to the newer parks. The older parks also elicited more satisfaction with scenery. This may be because the appearances of plant communities in older parks had enough time to reach balance and optimal size. Moreover, according to the green-space plans, the provisions of many kinds of recreational facilities were more stressed in the last versions of the plans. Therefore, within this context, park designers paid more attention to providing playgrounds and sporting areas. Another factor is that the older parks in Xi'an city usually covered smaller areas, and smaller parks received more positive assessments of the number and location of sporting facilities, resting facilities and playgrounds. This may indicate that smaller areas can also provide satisfactory recreational services, from the respondents' perspective.

Moreover, parks with areas of 5-10 ha usually received relatively low positive assessments of recreational services, especially regarding the number of playgrounds, sporting- and resting facilities. The parks with areas of 5-10 ha are residential parks according to the classification of Chinese parks. The results therefore may indicate that the designers of residential parks lack a consciousness of the importance of the recreational services of parks and therefore did not stress the provision of recreational facilities.

According to the respondents' assessment of recreational services, the cover of vegetation, multilayered vegetation, water and evergreens were positive factors. Thus, increasing the coverage of vegetation, water and evergreen species will increase the recreational satisfaction, especially with the scenery. However, a higher cover of trees and mature trees decreased the respondents' recreational satisfaction. The respondents thus may prefer to enjoy scenes that have abundant layers and are abundantly green during all four seasons, but prefer to rest and do sports in open spaces. Large crowns of trees and mature trees, such as woodlands, may interrupt the sight and sunlight. Therefore, multi-layered parks with some evergreen species were preferred by the respondents.

In general, this study provides a great deal of information on how to improve the recreational services of urban parks in Xi'an. However, due to the length limits of the questionnaire, detailed questions were not inquired, such as what types of scenery, sporting facilities and resting facilities were preferred by the respondents and what are the respondents' recreational preferences in individual parks.

8 Final Discussion and Conclusions

8.1 Discussion of the Results

In order to assess the ecosystem services of urban parks in Xi'an, this study developed a rapid non-monetary assessment method encompassing questionnaires and indicator assessments. The assessed indicators included vegetation, water, multi-layered vegetation, trees, mature trees and evergreen species. The rating rules of the indicators were composed of scales based on indicator proportions and simple aggregations. This simple method can be understood without the help of professionals. All the data needed for this method can be easily collected in different study areas. In China, few attempts have been made to use such methods, giving this study a certain pioneering character. Additionally, few public comments have been taken into consideration. Therefore, this method can be applied to other Chinese cities.

Using indicator assessments based on the types of vegetation structure, over half of the parks were found to have a medium value of regulating services. More parks showed high values of microclimate regulation than air quality regulation. Using questionnaires, it was found that the respondents considered that urban parks have a higher impact on microclimate regulation than on air quality improvement. Therefore, indicator assessments and respondents' assessments showed accordant results regarding regulating services. However, respondents considered that urban parks provided a low value of recreational services. Thus, the urban parks of Xi'an city as a whole provided a higher value of regulating services than recreational services.

Vegetation structure was an important determinant of both the respondents' subjective assessments and objective indicator assessments. Among the 22 investigated public urban parks, most had a limited number of types of land cover and vegetation structure, in conjunction with a large cover of impervious and less cover of mature trees and evergreens. This led to fewer parks having high-value ecosystem services, and many respondents wanted more ecosystem services in the parks. The vegetation characteristics and appearances were designed during the first stage of park construction, based on the directions of the master plan and the documentation of the green space plan. The older parks, providing special playgrounds and large areas of pavements, revealed a focus on recreational services during their time of construction. In fact, in the green spaces plans from the 1980s and 1990s, recreational services and playgrounds were paid more attention, while in the later versions of the plans the multifunctional green spaces and the sustainable development of the environment were brought into the foreground.

The green space plan of Xi’an city stressed the importance of recreational services and pointed out the necessity to provide recreational facilities, sporting facilities and playgrounds in all types of urban parks. However, the fact that the respondents were not satisfied with the recreational services of urban parks may indicate that it is not easy to achieve the goals set out for recreational services within the limited surface area of inner-city urban parks, especially in situations where urban parks are supposed to provide regulating services as well.

In the last two decades, the obviously increased number and area of urban parks demonstrate the attention paid to the development of green spaces by the government of Xi’an city. However, the very tense land use pressures limited the quantity and area of green spaces, and hence the speed of green-space development, compared with other cities. In Xi’an city, urban green spaces usually are built on vacant land or around historical relics, as stated in the master plans. At the city level, the southern area, and especially the southeast area, has a greater number and total area of parks than the other areas (see Figure 3.1). The unbalanced distribution of land resources between the southern and northern areas directly led to an unbalanced distribution of urban parks. In addition, over half of the urban parks have smaller areas of less than 10 ha. These smaller parks are always the older parks located within the second ring road. The other twelve parks, and especially the bigger ones, were built after the year 2000 and are located between the third and second ring roads. The older parks had various vegetation layers and compositions, with higher cover of multi-layered vegetation, trees, mature trees, and evergreens. Therefore, the urban parks in Xi’an city have unbalanced qualities. Although the number and areas of urban parks decreased toward the city center (Table 3.1), individual parks near the central areas showed increased provisions of regulating services and recreational services.

The limited area of urban parks was therefore not in conflict with the provision of ecosystem services in the parks investigated in this study. The small and medium-sized parks provided higher regulating and recreational services, because these smaller parks are usually older and hence have large tree canopies, abundant vegetation layers, and special playgrounds. By comparison, although larger parks have relatively larger areas of lawns and water, they could not provide a high value of ecosystem services, at least in part due to their much younger trees.

Among the socioeconomic variables assessed in this study, the visitors’ age was a significant factor. Older visitors were the predominant users of urban parks. They often visited more often and stayed longer in green spaces than the other visitors. They positively took part in activities in green spaces and held different perceptions, assessments and demands for green spaces than the other age groups. It is easy to understand the obvious differences between the younger and the older respondents, due to the physical limits and educational backgrounds of the senior citizens. These findings suggest that future green-space plans and designs should pay more attention to the older age group. Their use habits, perceptions and demands should be a priority, since they are the most active users and have different demands for green spaces.

In addition, park age and location influenced the respondents' assessments and demands for green spaces. Respondents from the older parks and the parks located within the second ring road expressed more positive assessments and anticipations for ecosystem services. As discussed above, the older parks and the parks near the inner-city areas definitely had different types of land cover and vegetation structures than the other parks. These parks often had a higher cover of various vegetation structures and playgrounds, and hence produced higher values of both regulating and recreational services. The results demonstrated that respondents' positive assessments can reveal the objective basis of the supply of ecosystem services, and their suggestions can therefore be used to plan green spaces.

Considering the influence of vegetation structure, it was found that respondents preferred to stay longer in the parks with 51-75% of multi-layered vegetation and most frequently used the parks with 26-50% of trees and evergreens. They preferred to do sports and relax in the parks with 26-50% cover of multi-layered vegetation and evergreens. Moreover, respondents highly perceived the importance of ecosystem services in the parks which were covered by 76-100% of multi-layered vegetation and trees, as well as those with 51-75% of mature trees and evergreens. They also tended to assess the ecosystem services more positively in the parks with 76-100% of trees and 51-75% cover of multi-layered vegetation and evergreens. At the same time, they expressed stronger demands for individual items of ecosystem services in the parks with 26-50% of multi-layered vegetation.

These findings showed that respondents' use habits and recreational activities, as well as their perceptions, assessments and demands for ecosystem services of green spaces were connected to different vegetation structures. However, it is difficult to find rational explanations for these connections. Nevertheless, a high cover (76-100%) of trees consistently had a positive influence on respondents' perceptions, assessments and demands. The results may indicate that the respondents can intuitively understand the benefits derived from a high tree cover.

Generally, the links among these findings are more complex. For example, respondents assessed the scenery as slightly positive in the parks with higher cover of vegetation and multi-layered vegetation, and expressed more demands for flowers in the parks with a higher cover of trees. This may indicate that respondents prefer scenery with layered vegetation, and the establishment of flowerbeds or scattered populations of wildflowers should be stressed in the parks that have a high cover of trees.

In the parks with higher cover of multi-layered vegetation, trees and evergreens, respondents perceived the importance of shading as high. They also expressed more need for shading in the parks with a higher cover of trees and mature trees. Such findings may indicate that shading is a very important service from the respondents' perspective, even in the parks that already have enough shading. However, the respondents' recreational activities were not influenced by shading (tree and mature tree cover). This may indicate that, compared to the recreational facilities, shading is not an important factor influencing the respondents' activities in green spaces.

In addition, the respondents generally voiced more positive assessments and more demands in the older parks located within the second ring road. This is likely because in those parks, the respondents were satisfied with the ecosystem services, such as vegetation types, scenery, and vegetation cover, but still anticipated better management and more safety.

8.2 Suggestions for Improving the Green Spaces of Xi'an

The results presented in chapters 4, 5, 6 and 7 can answer all the research questions proposed in Chapter 2. The assessment of ecosystem services generated by urban parks in Xi'an has enabled the recognition and understanding of the importance of vegetation within urban areas. The questionnaires enhanced the residents' awareness of the value of urban green spaces and encouraged them to take part in urban greening activities. This study has also demonstrated that the types of vegetation structure not only directly influence the provisions of regulating services, but also significantly influence the respondents' preferences for individual recreational activities, as well as their use habits, perceptions, assessments and demands for urban parks. These research findings thus contribute to the understanding of the multi-functionality of urban green spaces and enable their better planning and design. From the perspective of planning approaches, the study provides a possibility to incorporate concepts of ecosystem services into the design of individual green spaces and green-space structure planning.

Based on the results of this study, several general strategies can be proposed to sustain urban green spaces and thus maximize their ecosystem services, not only at the local level but also at city level:

(1) Maintaining Sufficient Green Spaces Requires Limiting the Land Use
At the scale of the whole city, urban planning can play a key role in establishing strategies to conserve existing green spaces, develop new green spaces, and connect isolated fragments (Lovell and Johnston 2009). Compared to other countries, Chinese cities are typically very densely populated and crowded with buildings and roads. For example, in Xi'an city, only Wen Jing Park and City Sport Park are located in the northern areas between the second and third ring roads (see Table 3.1). Clearly, it is impossible to rely on these two parks to satisfy the respondents' needs for recreational activities and environmental regulation in the surrounding areas. The government should thus plan more green areas during the urban development of this district in the future. There are still potential places, even if few, for green spaces. It is feasible to transform abandoned lands and closed factories into green spaces and to stipulate the greening of lands in the renewal of old districts. Furthermore, it is possible to green all the scattered public open lands such as backyards, car parks, squares and streets. Transforming such lands to other uses should be prohibited.

(2) To Maintain the Number of Vegetation Structure Types and Plant Species
Various types of land cover and vegetation structure could contribute more environmental benefits. For example, multi-layered vegetation could increase the stability of plant communities and maintain multi-aged vegetation structures to provide continuous ecosystem services over time. However, current urban green spaces in Xi'an are characterized by simple land cover and vegetation structure types. Overall, urban parks are dominated by simply-structured vegetation, pavements with scattered vegetation, and plain pavements. Vegetation types were unevenly distributed among the parks, and mainly included multi-layered trees covering shrubs and lawns, trees covering shrubs and lawns, and lawns at the time of this study. By contrast, evergreen broadleaf woodlands, shrubs, bamboos and flower beds were seldom found. In the future, a broader range of vegetation structures, and especially natural vegetation (e.g. grasslands, un-trimmed shrubs and trees) should be emphasized in the design of green spaces.

The types of vegetation structure within the urban green spaces of Xi'an are not optimal for microclimate regulation and air pollution removal, primarily due to their low proportion of mature trees. Trees, and especially mature trees can provide large canopies and hence large amounts of cool air in the summer. As discussed in the studies of McPherson (1994), C.L (2002) and Yin et al. (2011), large trees can also remove more pollutants from the air. In the studies of Jonsson (2004), Potchter et al. (2006), Andrade and Vieira (2007), and Tzoulas and James (2010), the large cooling effects of high and wide-canopied trees were demonstrated. In this study, trees in the parks located inside the third ring road were much younger than those inside the second ring road, because most of the green spaces located inside the third ring road were built after the 1990s. This problem may simply take time to resolve by itself, as the already planted trees inevitably mature and increase in size. However, the vegetation composition of green spaces in Xi'an is not ideal for air pollution removal due to the limited cover of evergreens. In some parks, e.g. Tang Yan Road Tang City Wall Park and Mu Ta Si Park, evergreen species should be emphasized much more, not only for the generation of regulating services, but also in order to provide green scenery in winter.

Selecting appropriate species and configuring vegetation in patterns that are unique to different functional purposes in urban parks could maximize their ecosystem services. For future planning, the choice of vegetation, and especially trees, should be based on their suitability for the urban environment and their ability to remove air pollutants. The criteria used for tree selection should consider: (1) Evergreen trees have a higher capacity for removing air pollutants due to longer foliage retention (Beckett et al. 1998; Nowak et al. 2006); (2) Fast growing trees usually can provide a surface for the adsorption of air pollutants soon after establishment (Nowak and Crane 2002); (3) The leaf characteristics will influence the deposition of air pollutants on the leaf surface. It stands to reason that hairy, resinous, scaly, and coarse surfaces can capture more particles than smooth leaves (Beckett et al. 1998); (4) If a tree is sensitive to certain pollutants, it cannot be used at a site close to the source of such air pollutants (Beckett et al. 1998); (5) Trees with high BVOC (biogenic volatile organic compounds) and pollen emission rates should be avoided in planning to improve the net air pollution reduction benefit of the green spaces (Haider 1996; Nowak 2000).

(3) To Balance the Provision of Regulating Services and Recreational Services

The design of ecosystem services in green spaces is a complex process. It should consider the provision of different ecosystem services, characteristics of the local- and surrounding environment, and different requests of users. In practice, the detailed information of individual parks would be investigated beforehand, including location, original vegetation and resources, main user groups, and surrounding environment.

In this study, parks that had a higher proportion of vegetation and water usually also had high values of ecosystem services. Water can provide strong evaporation and thus reduce the air temperature in summer. It also can provide the opportunity for many kinds of activities such as boating and fishing. However, in many cases it is not feasible to increase the amount of water bodies in parks because they are very costly to construct, especially in the case of large artificial lakes, pools, streams or fountains. Therefore, the construction of water bodies should depend on the local site conditions. For example, a naturally low-laying site with an abundance of natural water sources can be used to form a water body (Qiu 2009). Moreover, the costs of maintaining water bodies are also obviously higher than those of vegetation (Qiu 2009). This may explain why the water bodies in Xi'an are muddy and hence unsuitable for a lot of possible water-related activities such as swimming and playing in the water.

It seems contradictory to simultaneously seek optimal regulating- and recreational services. A higher cover of vegetation and water, multi-layered vegetation, trees, mature trees and evergreens will increase the provision of regulating services. However, from the respondents' perspective, the recreational services were the most satisfactory in the parks with a higher cover of vegetation, water and evergreens but lower cover of trees and mature trees. From the perspective of the specific parks, we can try to balance the regulating and recreational services with considerations of the surrounding land-use types. For example, parks that are located in areas with higher population densities will face severe pressures of visitors' daily use. By incorporating population statistics within the service areas of parks, a large number of residents can be used as an indicator of a stronger need for recreational services. Therefore, additional recreational facilities, such as benches, sporting facilities and playgrounds, will be required to satisfy the residents' daily needs. At the same time, these parks should provide microclimate regulation and air purification. Shrub cover should be reduced in order to create more useable spaces. Lawns and open soil can replace impervious surfaces. The increased area of lawns and open soils not only provides regulating services for air quality and temperature, but also offer spaces and fields for play and other leisure activities. In order to satisfy the visitors' use habits and aesthetic preferences, a high cover of dense trees should be avoided, and sparse woodlands can be an alternative. The thick foliage and underlying branches of mature trees, especially at heights lower than 5 m, should be clipped to maintain open sight lines and provide sufficient light. Resting and sporting facilities and playgrounds can be placed under the tree canopies or near the trees. All these approaches can be used to provide a balance of both recreational and regulating services in parks.

In addition, local environmental factors are always complex. For example, if a park is located near main roads, more cover of evergreen species and multi-layered vegetation, and even green belts, should be chosen in order to block air pollution and reduce noise. However, the green area in question may be a small park located near main roads in between high-density housing. It is thus difficult to answer the question which ecosystem services should be the focus of the design in such cases. Park designers should therefore consider which service is more important and urgently needed. Based on the questionnaire results from this study, the respondents usually prefer to use urban parks to enjoy scenery and greenery and to obtain a certain extent of contact with nature. Therefore, recreational services should be planned and emphasized first. Considering that the predominant users of urban parks in Xi'an are the elderly and children, quiet and peaceful places for relaxation and play should be designed, and designated playgrounds can be designed for children.

(4) To Incorporate Citizens' Suggestions into the Process of Green Space Planning

The results of the questionnaire survey indicate that the residents of Xi'an have a positive attitude towards urban green spaces and a widespread recognition of ecosystem services generated by green spaces, which shows that there are potential motives for public participation in urban greening projects. Future urban green spaces urgently need to place a special emphasis on qualified recreational services. For specific parks, user surveys should encourage more citizens to participate in the process of planning, design and management of their often-used green spaces. More detailed questions should be asked in the questionnaires, including the respondents' preferred types of scenery, resting and sports facilities, and their concrete suggestions for these items with details such as choice of plant species, plant configurations and the location of resting and sporting facilities and playgrounds. For different user groups, questions should be asked regarding what features of green spaces, e.g. percentage of trees, vegetation types and scenery styles, could increase their use frequencies and stay times?

(5) To Consider the Provision of Ecosystem Services at Individual-Park and City Level

Parks in large cities do not exist individually. They are connected with each other and with other types of green spaces, and hence form higher-order green space structures, which are part of the green-space system of the city as a whole. Therefore, it is necessary to consider the connection of different green spaces and to design individual parks within the context of the entire structure of green spaces.

At the city scale, all types of green spaces should be connected through the systems of main roads and streets. Urban parks provide ecosystem services for a large number of citizens at the scale of an individual district or even the whole city. By contrast, residential green spaces provide ecosystem services mainly at the scale of a single neighborhood. Parks and residential green spaces usually have larger areas and hence can be seen as green patches. These green patches are interconnected by street trees and roadside green spaces to form a green-space system. The integrated system can increase the provision of total ecosystem services if it is well-connected and distributed throughout the city.

(6) To Develop a System for Better Management

Better management is critically important in order to increase the benefits provided by existing green spaces in Xi'an. This means that it is necessary to select appropriate species and maintain the health of the vegetation, as well as to maintain a suitable tree density and complex vegetation structure. Existing trees should be preserved rather than transplanted or removed as is currently common practice in Xi'an. Developers should therefore be required to incorporate existing trees into development plans.

More financial support should be provided for the development and management of urban green spaces. The shortage of financial support may lead to insufficient development of urban green spaces and by extension an insufficient supply of ecosystem services. It is therefore necessary for the government to increase the greening budget to alleviate the chronic economic stresses in order to improve ecosystem services supplied by urban green spaces. Moreover, more effective institutions and regulations should be established to enable better management of urban green spaces. Although a number of related legislations and ordinances have been promulgated in Xi'an, there is a lack of enforcement. There is a misunderstanding that urban green spaces are state-owned land resources and can be used by government institutions without legal or administrative permission, and the Xi'an Landscape Bureau has little legal or administrative power to protect urban green spaces. A set of clear and equitable legal judgment mechanisms has to be established to guide the scientific management of urban green spaces.

In summary, the design of urban green spaces should consider their specific purposes such as environmental regulation, recreation, etc. An optimal quality of urban green spaces could be achieved through the design of multifunctional urban landscapes based on an appropriate vegetation structure, choice of species, and functional divisions. Public involvement in urban greening projects could be a major driving force, in addition to the political support, for the green structure planning of urban green spaces in Xi'an. It would be helpful if the public could accurately assess the ecosystem services. Finally, more opportunities should be provided for the residents to become involved in the planning, maintenance and conservation of urban green spaces.

8.3 Limits of This Study and Suggestions for Future Research

8.3.1 Limits and Suggestions for the Non-monetary Assessment Method

Traditional assessment methods used for regulating services usually rely on mathematical models, which require complex processing not only during the measurement and collection of indicators, but also during data computation. Moreover, suitable models need to be established and adjusted beforehand. This study attempted to develop a simple assessment method that can be used under the conditions of limited resources such as limited time and finances, or a lack of professionally trained personnel.

Generally, the assessment method of regulating services used in this study is based on a range of indicators, indicator ratings and aggregations. The main advantage of this method is its simple and rapid operation. The indicators included vegetation types, vegetation composition and biological characteristics (e.g. evergreen or deciduous). The values of the individual indicators were calculated visually based on their area of coverage. Therefore, the vegetation information can be easily collected without the need for complex processes or professional knowledge.

The indicator ratings used the ranges of individual indicators' coverage based on their positive influence on regulating services. The final assessment was aggregated using simple addition of the rating results. The complete assessment process is therefore simple and does not rely on complex models. However, the coarse rating rules could not provide numerical results and assessments.

In the future, this assessment method needs further information to make it more accurate while keeping it simple. The survey of detailed information related to vegetation / environment of green spaces and plant species should be covered, including the plant species, the height of the vegetation and the diameter at breast height (DBH) of trees. These data would help to assess the ecosystem services more accurately, since different plant species have different regulating ability of temperature and air pollutants. The species, the height of the vegetation and the DBH of trees can help to calculate the total leaf areas, and by extension the green biomass quantitates, and can hence be used to determine the regulating services in a quantitative way.

Furthermore, it is also possible to include environmental factors in the assessment of ecosystem services provided by green spaces. The local population and the land use types surrounding green spaces in a defined buffer zone, as well as the distance to the main roads, are important factors that influence the local demand for ecosystem services. Moreover, the density of population can influence citizens' demands for recreational services. The surrounding land use types can influence the balance of ecosystem services of green spaces. For example, downtown areas need more cooling from nearby green spaces, while industrial areas need more air purification by neighboring vegetation. It will be beneficial to assess these environmental factors in the future, in order to plan and design specific green spaces to provide maximal, balanced ecosystem services.

8.3.2 The Limits and Suggestions for the Questionnaires

In spite of their simplicity, efficacy and usefulness, there are some deficiencies in the questionnaires used in this study. Based on the questionnaire results, it is clear that more thorough questionnaires including a range of further questions can be designed in the future. Firstly, the number of questionnaire surveys in specific parks was limited due to time constraints. In fact, the number of questionnaires in the majority of individual parks was less than 20, and therefore lacked statistical weight. In future studies, the questionnaires conducted in individual parks should encompass more participants and more focused questions.

Secondly, more detailed questions should be asked in order to further investigate the respondents' perceptions and attitudes. Some general questions can be asked in any type of green space. For example, respondents can always be asked if an increase of the quantity and quality of water bodies, provision of clean air, more recreational facilities, or a higher number of plants and animals will enhance their satisfaction with the investigated green spaces. It is also possible to ask the respondents about their preferred vegetation types and configurations. These questions could help park designers to find out which type of scenery is welcomed. Some questions should help to optimally distribute the sporting and resting facilities in green spaces, such as asking about the respondents' favorite sports, or where benches should be located. Furthermore, questions aimed at specific green space design can be considered.

This study has demonstrated that different social groups, park characteristics and vegetation structures lead to different user behaviors, as well as to different assessments, perceptions and demands for ecosystem services of green spaces. In order to satisfy different user groups, focused questions should be asked, such as what is the respondents' favorite type of green space. Answers can be offered in the form of pictures, such as green spaces located away from roads, or spaces enclosed by high trees or shrubs, etc. The answers to these questions can reveal the preferred types of scenery in green spaces. Also, for individual parks, we can take pictures of different vegetation structures and ask visitors which best represents their favorite scenery and which types would provide better regulating services in their opinion.

8.3.3 Suggestions for Future Studies

This study is a pioneering attempt at exploring the multi-functionality of urban ecosystems and assessing the ecosystem services provided by urban green spaces. As such, it is limited to the assessment of regulating- and recreational services of green spaces. Other ecosystem services, such as psychological benefits, water infiltration and biodiversity, which are also important for the sustainable development of urban ecosystems and the quality of urban life, were not included. In the future, more comprehensive studies that include different kinds of ecosystem services generated by urban green spaces could be conducted.

Moreover, additional integrated methods, such as using questionnaires and observations to support or provide demonstrations, can be used in the future. These approaches can help us to advance the provision of ecosystem services in useful ways. For example, at the level of specific parks, we can ask users about their favorite recreational activities in green spaces. On the other hand, we can observe or track users' physical activities directly at certain times (Cohen et al. 2011 and Fjortoft and Sageie 2000), such as in the morning (7:00- 9:00) and evening (18:00-21:00). In order to investigate the provision of recreational facilities, we can ask visitors about their preferred places to have a rest in green spaces, and observe where visitors prefer to stop and sit.

Last but not least, in order to achieve the aims surrounding the provision of optimal ecosystem services by green spaces, and to cater to the different types of users, we should consider not only the visitors' socioeconomic backgrounds but also their use groups. The user groups can be divided by their frequent activities in green spaces, mainly into active (e.g. walking, walking a dog, exercising, jogging, cycling and playing games) and passive users (e.g. breathing fresh air, reading, sightseeing, relaxing, social contact and interaction, or enjoying and watching nature). Based on this, the relationships between the respondents' perceptions / assessments / demands for ecosystem services of green spaces and their use groups can be analyzed. We can therefore hypothesize that, for example, respondents who think that shading is the most important service belong to user groups that prefer relaxing or reading, respondents who want more recreational facilities belong to user groups who enjoy exercising, and respondents who regard aesthetics as important or want more vegetation belong to groups who prefer relaxing or sightseeing.

Taken together, this pioneering study thus demonstrates the feasibility of using simple questionnaire- and mapping-based surveys to elucidate the provision and demand for ecosystem services in urban green spaces, and paves the way for similar, but also more detailed analyses in many Chinese cities in the future.

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Appendixes and Annexes

Appendix 1: Profiles of the six urban parks used for pre-testing the methodology

Park name	Area (ha)	Year built	Location in the city	Park type
Lian Hu Park	5.25	1916	City center, inside First Ring Road	Residential park
Yong Yang Park	11.24	2006	South-west, inside Third Ring Road	District comprehensive park
Feng Qing Park	22.52	2004	South-west, inside Second Ring Road	Municipal comprehensive park
City Sports Park	33.84	2006	North, inside Third Ring Road	Sports park
Xing Qing Park	48.99	1958	South-east, inside Second Ring Road	Municipal comprehensive park
Qu Jiang Yi Zhi Park	50.67	2008	South-east, inside Third Ring Road	Municipal comprehensive park

Appendix 2: Survey sheet 1 – pre-test table of land cover within urban parks (sources: Sekliziotis, 1980; Pauleit and Duhme, 2000; Hermy and Cornelis, 2000 and Cornelis and Hermy, 2004)

Land cover types	Subdivisions of land covers	Park name:_______
Built / Buildings		
Roads		
Car parks		
Pavements / concrete surfaces		
Open soils		
Vegetation	Forest	
	Deciduous wood	
	Coniferous wood	
	Mixed wood	
	Trees	
	Tree rows	
	Shrubs	
	Hedges	
	Lawns	
	Mown grassland as sports fields	
	Turf grass	
	Rough grass	
	Infested grass	
	Pastures	
	Grasslands	
	Hay meadows	
	Tall herb vegetation	
	Flower beds	
	Vegetables	
	Arable crops	
Water	Water / freshwater	
	Pools	
	Brooks	
Supplementary types		

(Use a √ to mark the blank box under the park name column. If the land cover type is not shown in the given types, it should be recorded as a supplementary type)

Appendix 3: Survey sheet 2 – pre-test table of vegetation structure within urban parks

Patch number	Vegetation layers (1/2/3/>3）	Vegetation composition	Height of vegetation MT: ≥10m; T: 5-10 m; S:< 5 m; H: <10cm / 10-20cm / 20- 50cm / 0.5-1m / 1-2m
1			MT: T: S: H:
2			MT: T: S: H:
3			MT: T: S: H::
…			MT: T: S: H:

Note:
1) For types of land cover and vegetation, refer to Appendix 2;
2) Vegetation layers included one layer, two layers, three layers and multilayer;
3) Apart from vegetation layers, vegetation composition was recorded as found on-site, such as multi-layered groups of trees covering shrubs and lawns, trees covering groups of shrubs and lawns, trees covering groups of shrubs, woodlands or lawns;
4) Abbreviations: MT: mature trees; T: trees; S: shrubs; H: herbs.

Appendix 4: Survey sheet 3 – investigative table of land cover and vegetation structure within urban parks

Park name:_____________

Date: ________________

Patch number	Land covers	Vegetation layers and compositions (1/2/3/>3)	Low tree cover (5-10m)				Tall tree cover (tree height ≥ 10m)				Evergreen broadleaf tree cover Evergreen coniferous tree cover Deciduous broadleaf tree cover				Shrub cover and evergreen shrub cover (<5m)				Herb cover (lawn <10 cm /grassland <20cm)				Other information (P/S/SF/RF)
1			C1	C2	C3	C4	C1	C2	C3	C4	EBC1	EBC2	EBC3	EBC4	ESC1	ESC2	ESC3	ESC4	C1	C2	C3	C4	
											ECC1	ECC2	ECC3	ECC4									
											DBC1	DBC2	DBC3	DBC4	SC1	SC2	SC3	SC4					
2			C1	C2	C3	C4	C1	C2	C3	C4	EBC1	EBC2	EBC3	EBC4	ESC1	ESC2	ESC3	ESC4	C1	C2	C3	C4	
											ECC1	ECC2	ECC3	ECC4									
											DBC1	DBC2	DBC3	DBC4	SC1	SC2	SC3	SC4					
3			C1	C2	C3	C4	C1	C2	C3	C4	EBC1	EBC2	EBC3	EBC4	ESC1	ESC2	ESC3	ESC4	C1	C2	C3	C4	
											ECC1	ECC2	ECC3	ECC4									
											DBC1	DBC2	DBC3	DBC4	SC1	SC2	SC3	SC4					
4			C1	C2	C3	C4	C1	C2	C3	C4	EBC1	EBC2	EBC3	EBC4	ESC1	ESC2	ESC3	ESC4	C1	C2	C3	C4	
											ECC1	ECC2	ECC3	ECC4									
											DBC1	DBC2	DBC3	DBC4	SC1	SC2	SC3	SC4					
5			C1	C2	C3	C4	C1	C2	C3	C4	EBC1	EBC2	EBC3	EBC4	ESC1	ESC2	ESC3	ESC4	C1	C2	C3	C4	
											ECC1	ECC2	ECC3	ECC4									
											DBC1	DBC2	DBC3	DBC4	SC1	SC2	SC3	SC4					

(Use a √ to mark the answer under the fourth to ninth column; the second, third and tenth column should be recorded as observed)

Explanations and abbreviations:

1) Land cover types: there are six optional types of land cover based on the pre-test sheet (V: vegetation; P: pavements; PV: vegetation over pavements; PG: playgrounds; B: buildings; W: water bodies);
2) Lawn means frequently mown grass whereas grassland means naturally growing grass;
3) Abbreviations: C: coverage; SC: coverage of shrubs; ESC: coverage of evergreen shrubs; EBC: coverage of evergreen broadleaf trees; ECC: coverage of evergreen coniferous trees; DBC: coverage of deciduous broadleaf trees; P: pavement; S: soil surface; SF: sports facilities; RF: recreational facilities;
4) Each vegetated patch was assigned to class 1 (0-25%), 2 (26-50%), 3 (51-75%) or 4 (76-100%). To abbreviate the four classes for different layers of vegetation, the following acronyms were used: C1,SC1,ESC1,EBC1,ECC1,DBC1 /C2,SC2,ESC2,EBC2,ECC2,DBC2 / C3,SC3,ESC3,EBC3,ECC3,DBC3 / C4,SC4,ESC4,EBC4,ECC4,DBC4.

Appendix 5: Questionnaire

Park name:

Date:

Investigator:

Note: Please place √ in the □ at the beginning of the choice answer.

Part I Personal Information

Sex: □female □male

Age: □15-25□26-45□46-65□>65

Family status: □single □couple □3(parents and a child) □>3 (parents and more than one child)

Vocation: □student □employed □self-employed □unemployed □retiree

Part II Use of Urban Green Spaces

1. Where do you go for your daily recreation (please tick as appropriate)?

	Green spaces	Very often	Often	Occasionally
1	Public parks			
2	Residential green spaces			
3	Roadside green spaces and squares			
4	Green spaces near work place or school			
5	Other (please state)			

2. How long do you spend travelling to the green spaces you usually frequent (please tick as appropriate)? (min=minutes)

6	<5 min	
7	5-15 min	
8	16-30 min	
9	>30 min	

3. How often do you visit these green spaces (please tick as appropriate)?

10	Daily	
11	Several times per week	
12	Weekly	
13	1-3 times per month	
14	Monthly	
15	Several times per year	
16	Less	

4. At what time do you use these green spaces (please tick as appropriate)?

	Time of use		Very often	Often	Occasionally
17	Time of the day	In the morning (before 12:00)			
		In the afternoon (12:00-18:00)			
		In the evening (after 18:00)			
18	Time of the week	Weekdays			
		Weekends			

5. How long do you normally remain in these green spaces (please tick as appropriate)?

19	Less than one hour	
20	One to two hours	
21	Half a day	
22	Nearly a whole day	

6. What is your main recreational activity when you use green spaces (please tick as appropriate)?

		Very important	Important	Not important	Nether important nor unimportant
23	To do sport				
24	To use the recreational facilities (e.g. fitness equipment)				
25	To relax / reduce stress				
26	To spend time in a quiet and peaceful area				
27	To have fun with friends or play with family				
28	To enjoy the beautiful views				
29	To enjoy the surrounding greenery				
30	To be in contact with nature				
31	To learn about plants and animals				
32	To enjoy the weather and get fresh air				
33	To enjoy the cooler climate in summer				
34	To walk the dog				
35	Other (please state)				

Part III Perspectives and Attitudes towards the Ecosystem Services of Urban Green Spaces

7. What type of urban green space is most important for you (please tick as appropriate)?

		Very important	Important	Not important	Nether important nor unimportant
36	Near my residence (or work place, or school)				
37	Big city parks, even if further away				
38	Parks outside the city				
39	Other (please state)				

8. How do you feel about the services provided by urban green spaces (please tick as appropriate)?

		Very important	Important	Not important	Nether important nor unimportant
40	O_2 release				
41	CO_2 sequestration				
42	Wind protection				
43	Increased air humidity				
44	Lower air temperature				
45	Shade				
46	Air quality improvement				
47	Noise reduction				
48	Wildlife habitats				
49	Species conservation				
50	Water-soil conservation				
51	Places for recreational activities				
52	Aesthetic improvement				
53	Cultural and educational benefits				
54	More contact with nature				
55	Neighbor-social interaction				
56	Economic value (e.g. cultivation of wood and fruits)				
57	Other (please state)				

9. How do you feel about the urban green spaces of Xi'an city (please tick as appropriate)?

		Excellent	Good	Fair	Unclear	Poor
58	Amount of green areas					
59	Vegetation diversity					
60	Recreational opportunities					
61	Ecological functions (e.g. decreased temperature, lower air pollution)					
62	Management/maintenance of the green spaces					
63	Other (please state)					

10. What is your assessment of the quality of frequently used green spaces (please tick as appropriate)?

		Excellent	Good	Fair	Unclear	Poor
	Management of green spaces					
64	Cleanliness					
65	Safety					
	Amount of green areas					
66	Vegetation cover ratio					
	Species conservation (vegetation and animals)					
67	The number of plant types					
68	The number of wild animal types (e.g. birds and insects)					
	Recreational opportunities					
69	Scenic beauty					
70	The number of sporting facilities					
71	The location of sporting facilities					
72	The maintenance of sporting facilities					
73	The number of resting facilities (e.g. tables and benches)					
74	The location of resting facilities (e.g. tables and benches)					
75	The maintenance of resting facilities (e.g. tables and benches)					
76	The area of playgrounds					
77	The location of playgrounds					
78	The maintenance of playgrounds					
	Ecological functions (e.g. decreased temperature, lower air pollution)					
79	Microclimate (e.g. cooling, tree shade, humidity and wind)					
80	Air quality					

		Excellent	Good	Fair	Unclear	Poor
81	The area of a body of water					
82	Water quality (if in connection with a water body)					
83	Overall assessment of this site					

11. What would you like to see improved in your frequently used green spaces (please tick as appropriate)?

		Strongly need	Need	Do not care	Do not need
84	More shade				
85	More wind-protected sites				
86	More quiet places				
87	More facilities for sports and exercise				
88	More play areas for children				
89	More resting facilities (e.g. benches / tables)				
90	More cafes / restaurants				
91	More bodies of water				
92	More flowers				
93	More opportunities to watch nature (vegetation, birds, etc.)				
94	Better management (e.g. better maintenance of plantings, facilities / less litter)				
95	More convenient and safer transportation to the green spaces				
96	Other (please state)				

Annex 1 Land cover types, characteristics and examples within urban parks of Xi'an

Land cover type	Sub-types	Characteristics	Examples
Vegetation	Lawns	Continuous large fields of mown grass, with height of less than 10 cm	
	Flower beds	Continuous fields of flowers, with height varying from 20-100 cm	
	Water plants	Continuous fields of aquatic plants living in or near water, with height varying from 20-100 cm	
	Bamboos	Continuous fields of bamboo, with height varying from 1-2 m	

Land cover type	Sub-types	Characteristics	Examples
Vegetation	Shrubs	Continuous groups or rows of shrubs trimmed or growing naturally, with heights of less than 5 m	
	Evergreen broadleaf woodlands	Continuous tree canopy coverage dominated by evergreen broadleaf trees, with heights of more than 5 m	
	Evergreen coniferous woodlands	Continuous tree canopy coverage dominated by evergreen coniferous trees, with heights of more than 5 m	
	Deciduous broadleaf woodlands	Continuous tree canopy coverage dominated by deciduous broadleaf trees, with heights of more than 5 m	

Land cover type	Sub-types	Characteristics	Examples
Vegetation	Trees covering shrubs	A mixture of groups or rows of trees and shrubs	
	Trees covering lawns	A mixture of groups or rows of trees covering lawns	
	Shrubs covering lawns	A mixture of groups or rows of shrubs covering lawns	
	Trees covering shrubs and lawns	A mixture of groups or rows of trees, shrubs and lawns	

Land cover type	Sub-types	Characteristics	Examples
Vegetation	Multi-layered trees covering shrubs and lawns	A multi-layered mixture of groups or rows of trees, shrubs and lawns	
Pavements with scattered vegetation		Sealed surface (≥50% of the field area) covered with scattered vegetation; the dominant feature is the sealed surface	
Pavements		All sealed surfaces that are not part of the road system, including squares, sealed sport courses or enlarged road areas	
Playgrounds		Open fields with recreational facilities	

Land cover type	Sub-types	Characteristics	Examples
Buildings	Business buildings	Buildings for commercial use (e.g. offices, public toilets and other facilities)	
	Garden architecture	Buildings with recreational and aesthetic functions	
Water bodies	Lakes	Large water areas (e.g. manmade lakes)	
	Fountains	Water jets with a purely recreational and aesthetic purpose	

Annex 2: Land Cover and Vegetation Structures Within the 22 Investigated Urban Parks of Xi'an

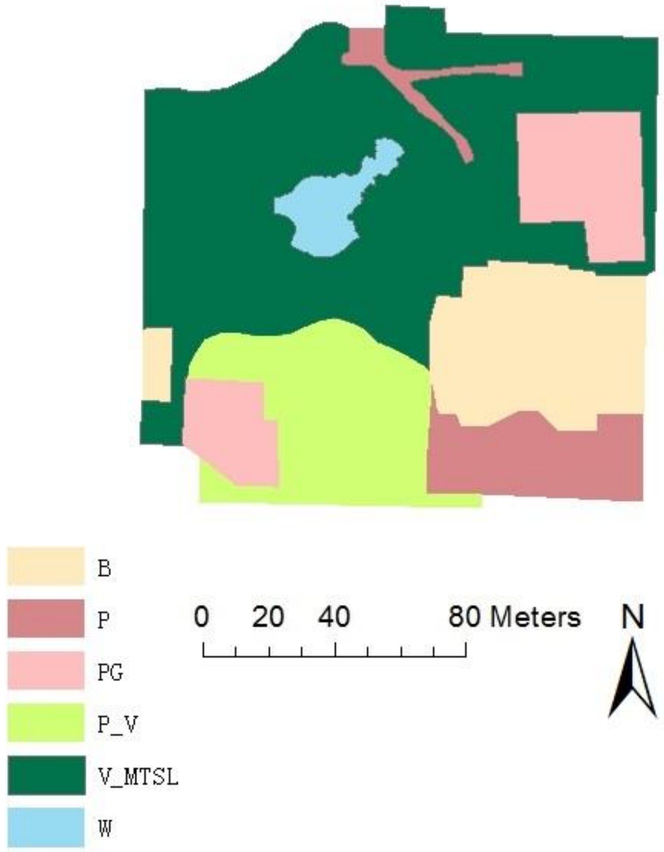

Figure 1 Land cover and vegetation structure in Children's Park

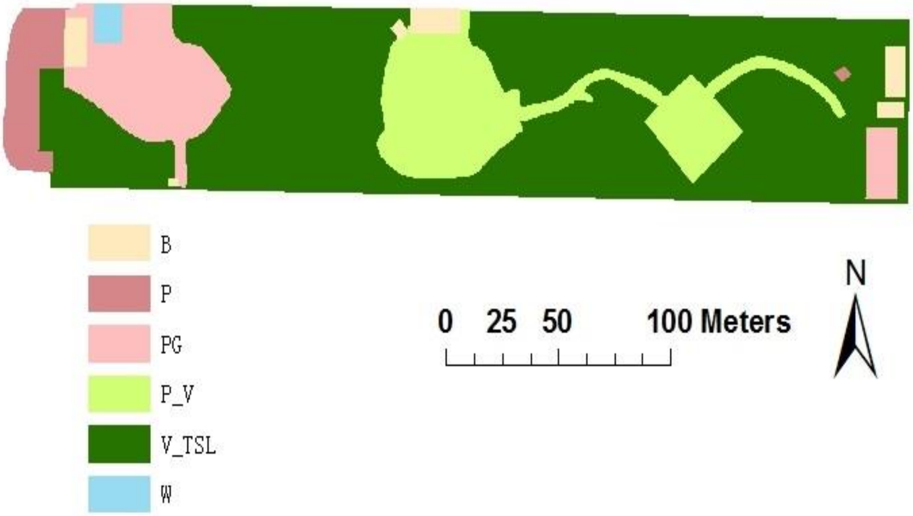

Figure 2 Land cover and vegetation structure in Tu Men Park

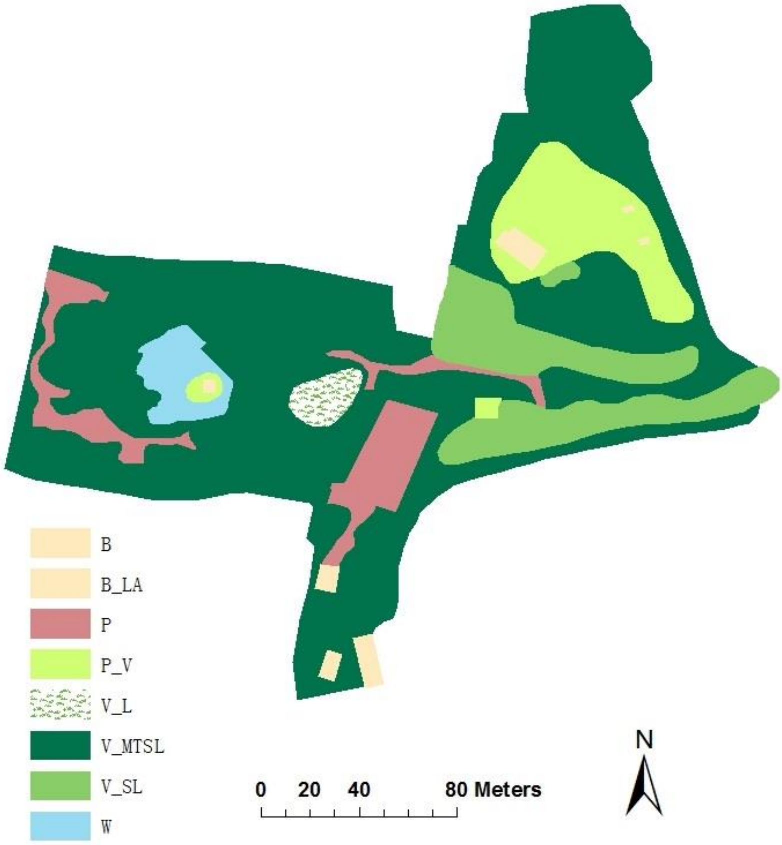

Figure 3 Land cover and vegetation structure in Fang Zhi Park

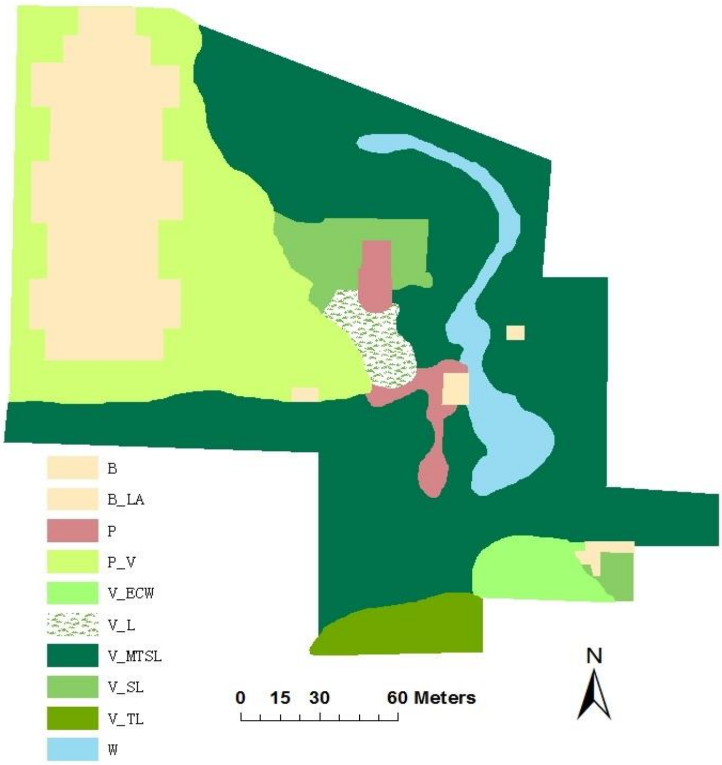

Figure 4 Land cover and vegetation structure in Ci En Si Yi Zhi Park

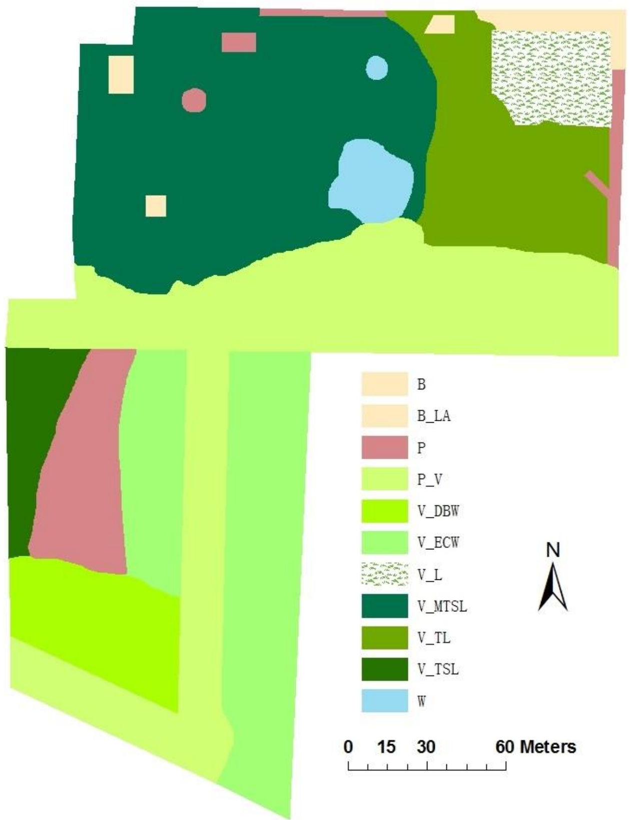

Figure 5 Land cover and vegetation structure in Xi Qu Da Guan Yuan

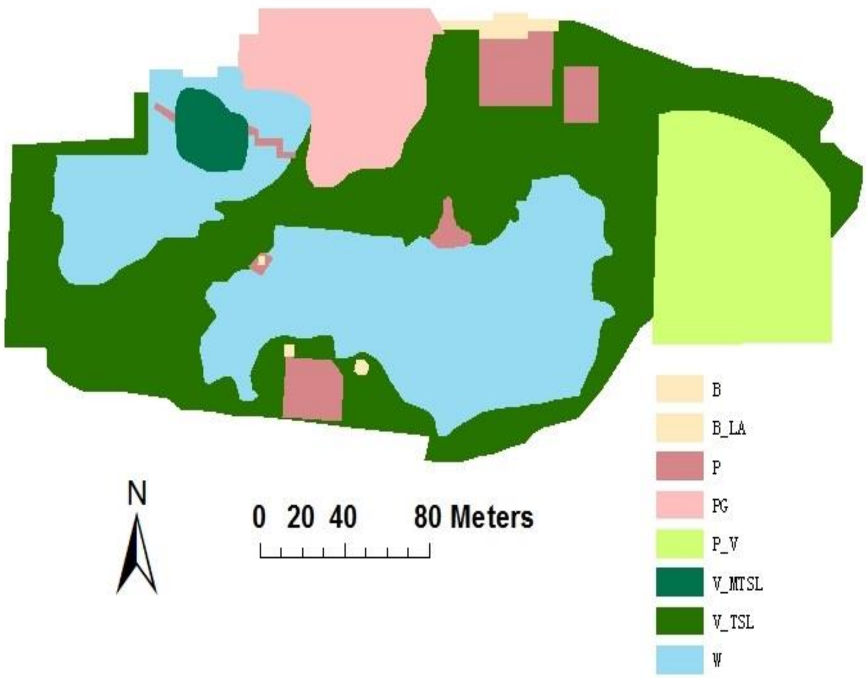

Figure 6 Land cover and vegetation structure in Lian Hu Park (water plants distributed within the water area)

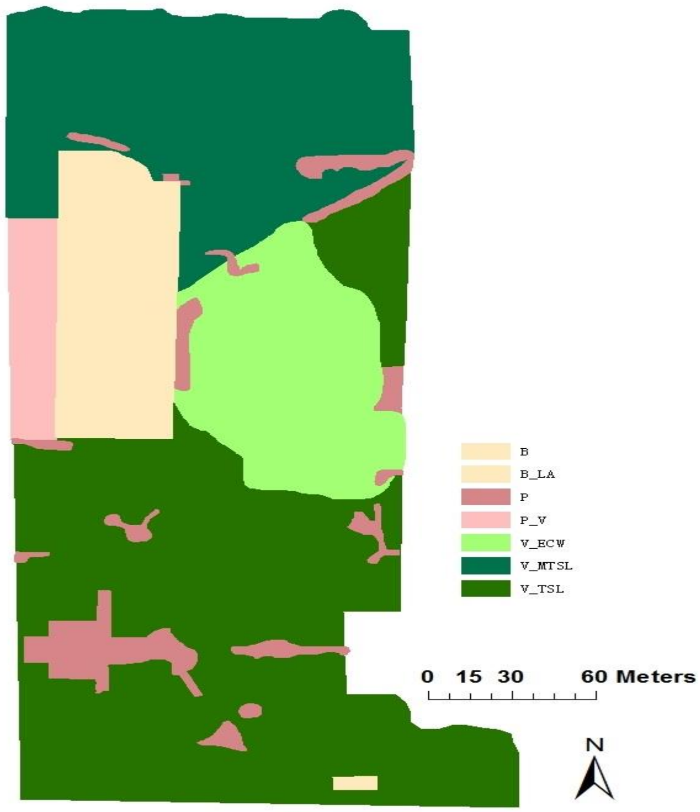

Figure 7 Land cover and vegetation structure in Min Su Park

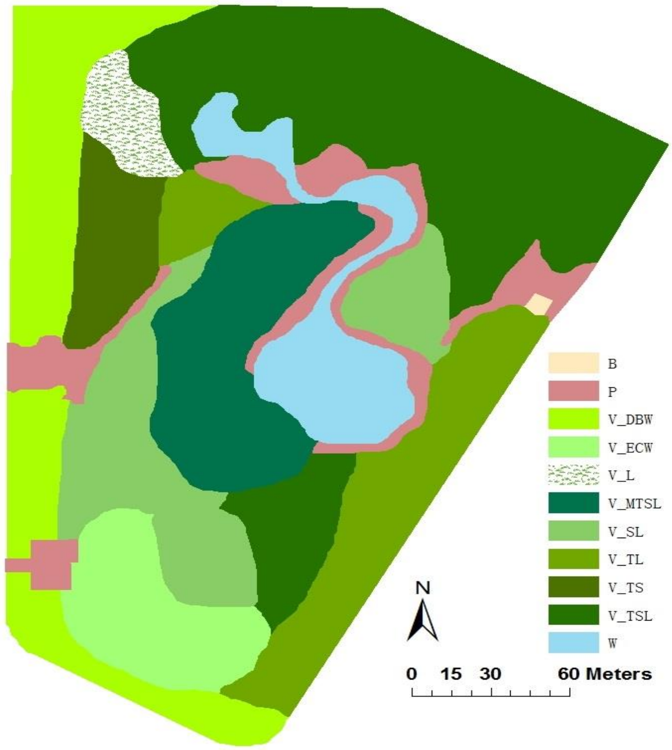

Figure 8 Land cover and vegetation structure in Xin Ji Yuan Park

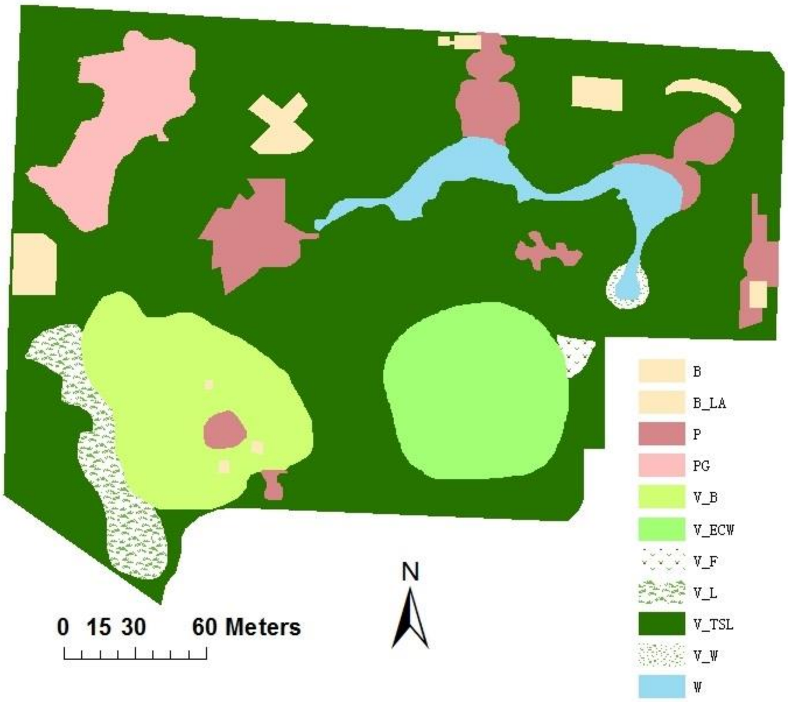

Figure 9 Land cover and vegetation structure in Wen Jing Park

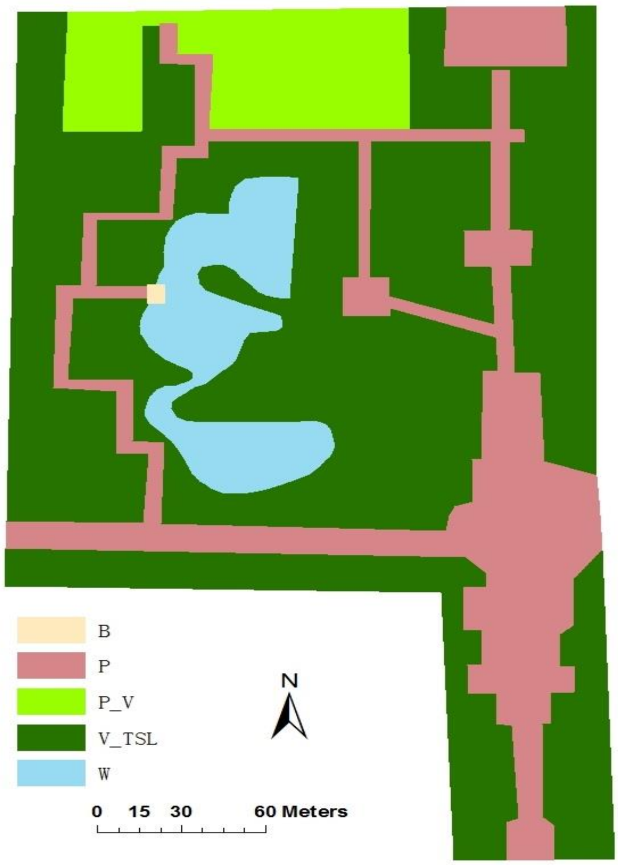

Figure 10 Land cover and vegetation structure in Mu Ta Si Park

Figure 11 Land cover and vegetation structure in Mu Dan Yuan

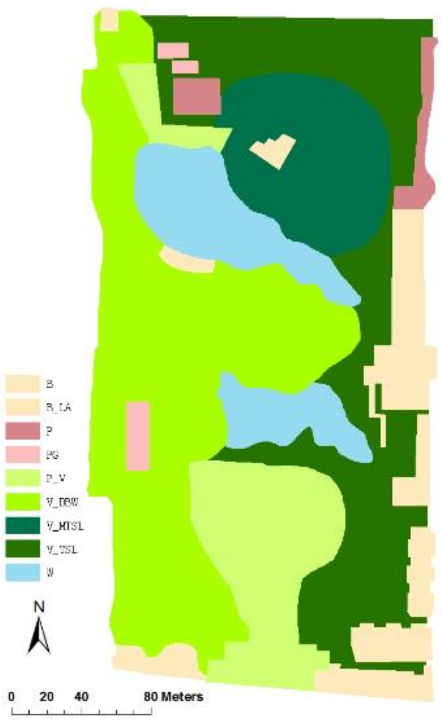

Figure 12 Land cover and vegetation structure in Lao Dong Park

Figure 13 Land cover and vegetation structure in Ge Ming Park

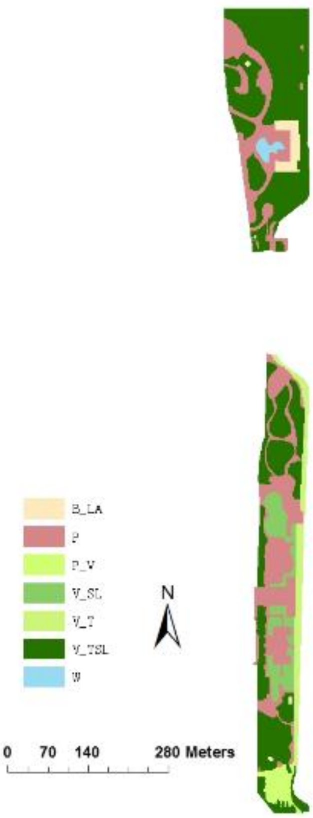

Figure 14 Land cover and vegetation structure in Huan Cheng Xi Yuan

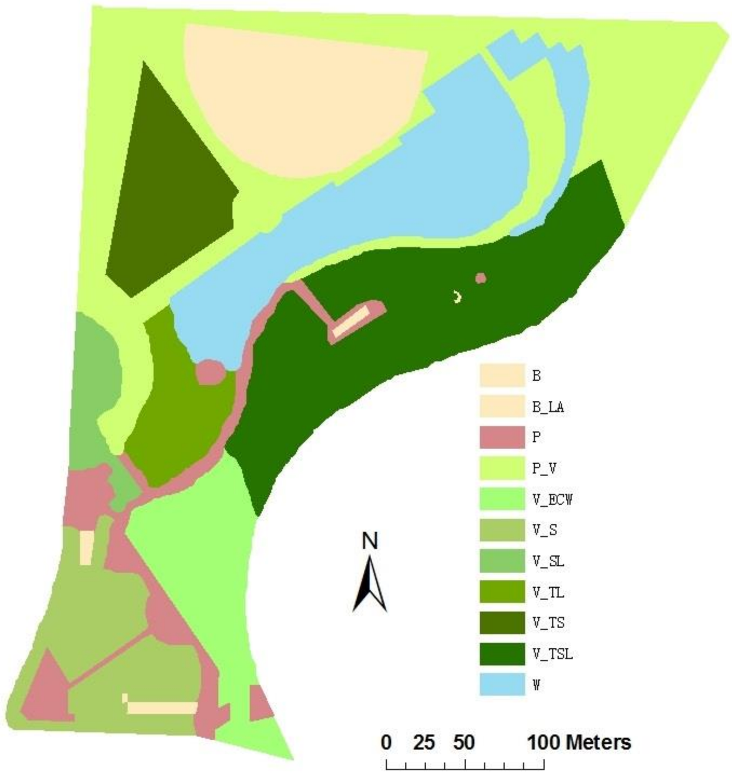

Figure 15 Land cover and vegetation structure in Yong Yang Park

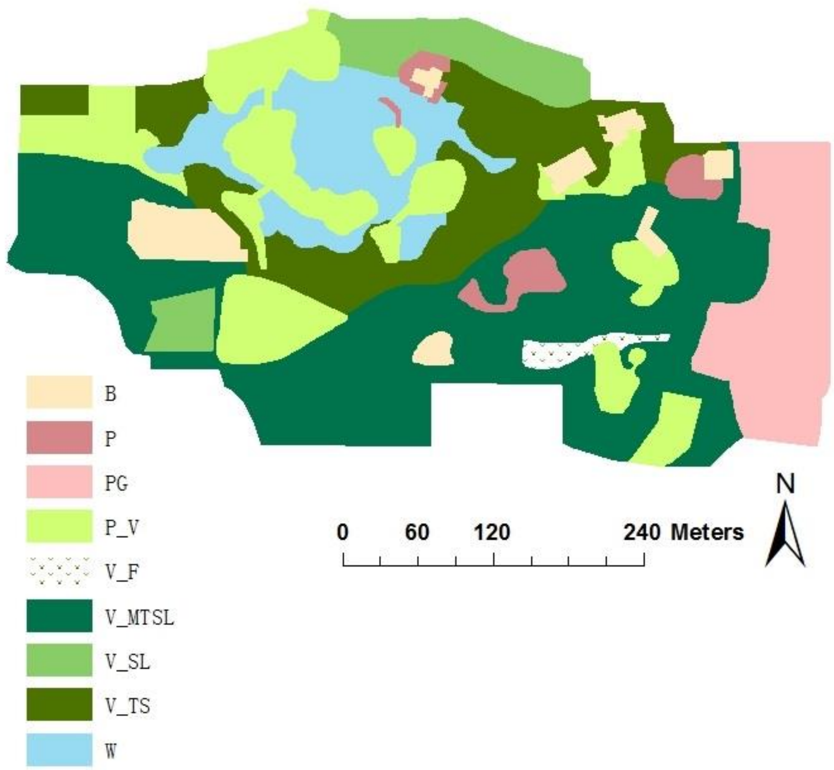

Figure 16 Land cover and vegetation structure in Chang Le Park

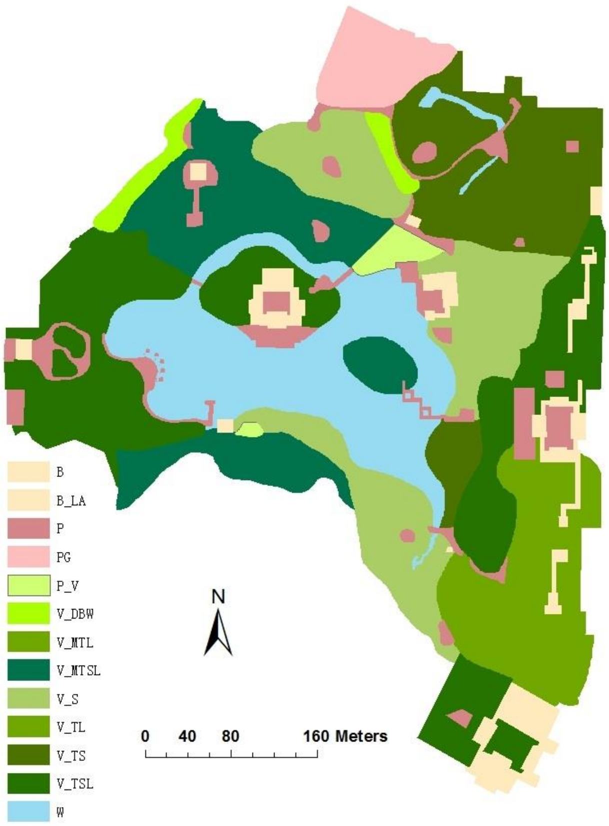

Figure 17 Land cover and vegetation structure in Feng Qing Park

Figure 18 Land cover and vegetation structure in Qu Jiang Tang City Wall Park

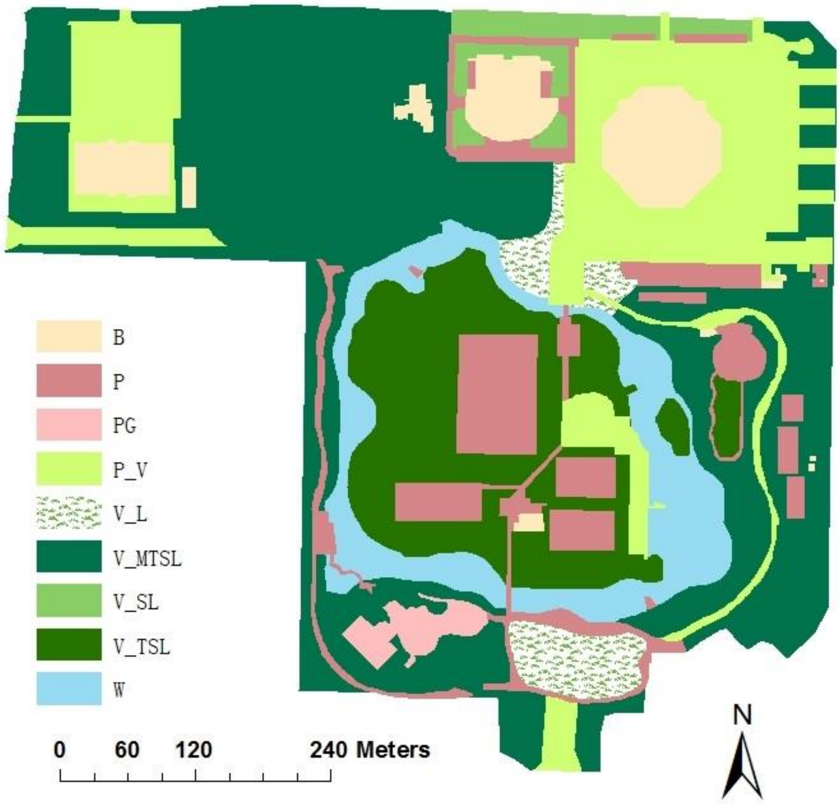

Figure 19 Land cover and vegetation structure in City Sports Park

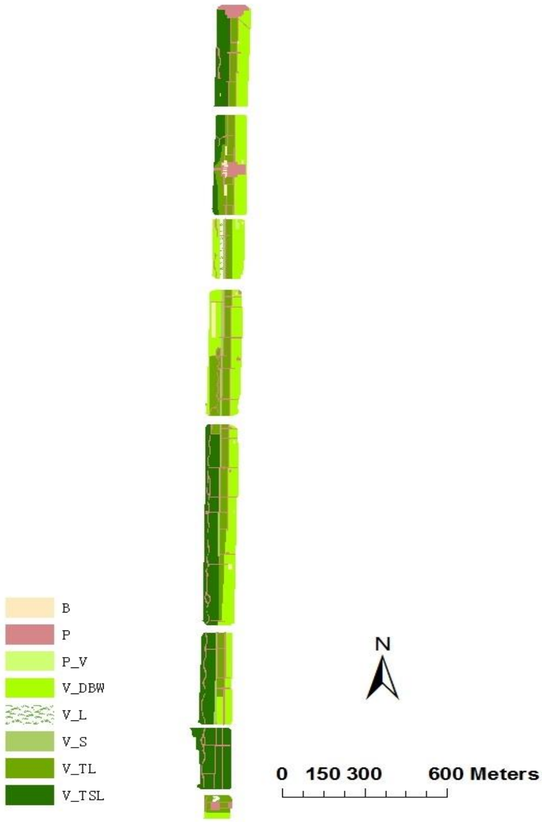

Figure 20 Land cover and vegetation structure in Tang Yan Road Tang City Wall Park

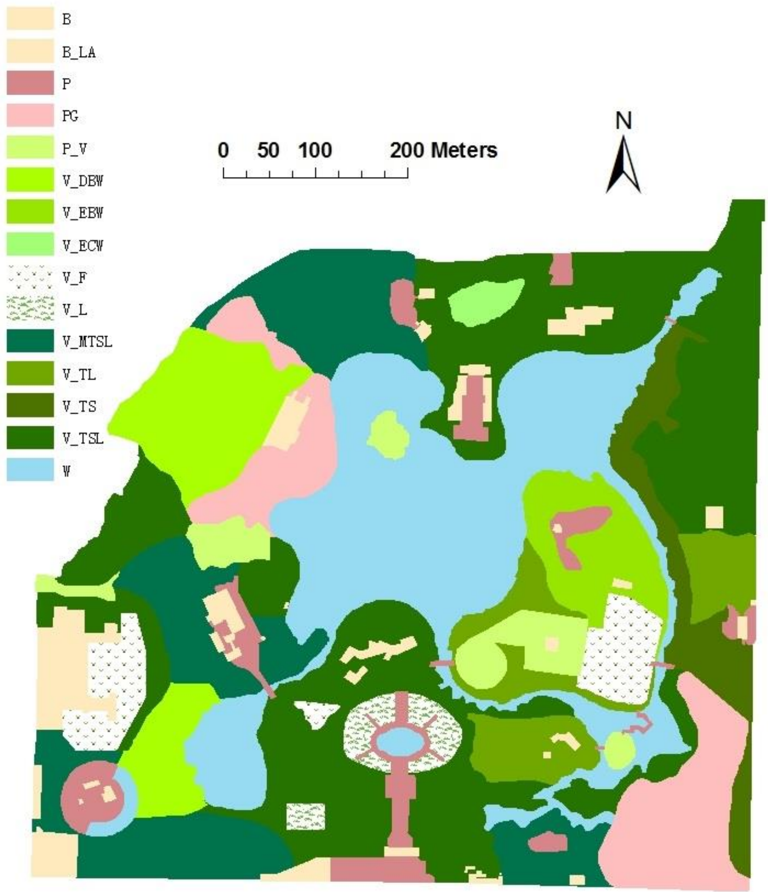

Figure 21 Land cover and vegetation structure in Xing Qing Park

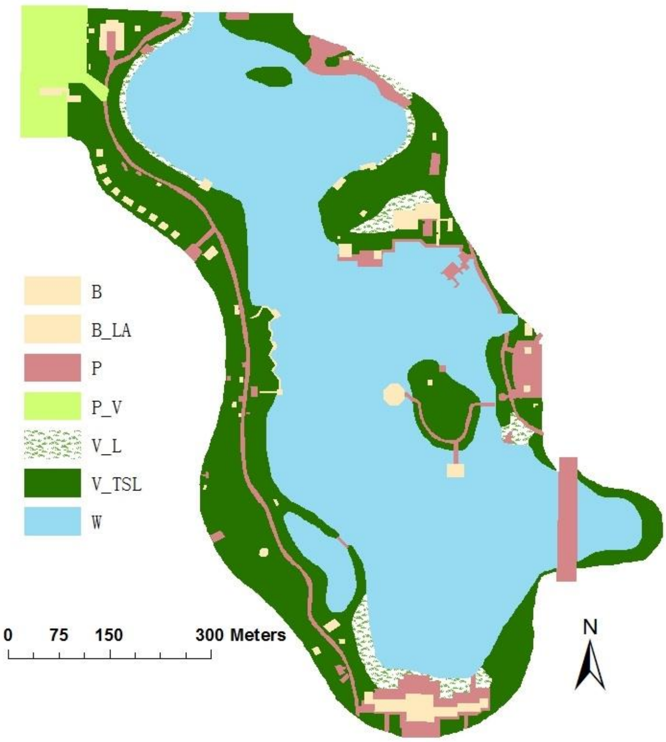

Figure 22 Land cover and vegetation structure in Qu Jiang Yi Zhi Park

Abbreviations of Figure 5.1-5.22: P: Pavements; P_V: Vegetation covering pavements; PG: Playgrounds; B: Buildings; B_LA: Landscape architecture; W: Water bodies; V_L: Lawns; V_F: Flower beds; V_W: Water plants; V_B: Bamboos; V_S: Shrubs; V_EBW: Evergreen broadleaf woodlands; V_ECW: Evergreen coniferous woodlands; V_DBW: Deciduous broadleaf woodlands; V_TS: Trees covering shrubs; V_TL: Trees covering lawns; V_SL: Shrubs covering lawns; V_TSL: Trees covering shrubs and lawns;V_MTSL: Multi-layered trees covering shrubs and lawns.

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Educations

9/2005-6/2008	Major in Forest Genetic and Breeding for master degree at Northwest A&F University, Yangling, China
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9/1996-9/1999	26th Middle School of Xi'an, Shaanxi, China
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Work Experiences

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9/2005-9/2006	Part-time teacher in Yangling vocational & technical college

Papers

CaiTong, Guo-Junzhan, RuanYu (2008). Investigation on resource and gardening application of colorful plants in Xi'an. *Journal of Northwest College of Forestry,* 23(4) 196-199

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