Rethinking lawns as prevalent elements of urban green spaces

Exploring sustainable lawn alternatives in Chinese mega-cities from social-cultural and ecological perspectives

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Abstract

The lawn is one of the most visible elements of urban green spaces and Western landscape styles. China has seen a dramatic increase in planted lawn areas. However, there is an urgent need for sustainable lawn alternatives (SLTs) in China due to serious threats to the urban environment from intensive lawn maintenance and cultural inadequacy of lawns. This thesis attempts to examine the reasons behind the historical context and current situation of lawns in China and offers suggestions for SLTs via a case study of Xi'an using transdisciplinary research framework from social-cultural and ecological perspectives.

A historical study was performed on reasons of lawn development in Chinese cities and modern European and Chinese examples of lawn alternatives by reviewing literature and through field observation. Face-to-face interviews, questionnaires and observations were conducted to evaluate how stakeholders and park visitors perceive lawns and how this affects their decisions in designing, managing and using lawns and lawn alternatives. To identify how the design and management shape plant and pollinator diversity, biodiversity inventories were conducted. Finally, results from the three studies were analysed following a framework based on theories in landscape sustainability and ecosystem services.

The results suggested that the Chinese people's paradigm of lawns is influenced by westernisation and globalisation after the 1840s. Lawns evolve from changes in the relationship between humans and the environment. In classical Chinese gardens, groundcover species were used according to their ecological characteristics and suitability to site conditions. Lawns in Xi'an have the same core grass species as lawns used in geographically distant regions, contributing to lawn plant species homogenisation worldwide. Intensive maintenance negatively affected plant species diversity and native plant species, while in more planned green spaces, older and larger lawns harbour diverse plant species and native plant species. The aesthetic value and regulating services of lawns are mostly recognised by park visitors and stakeholders although lawns impair the provision of some regulating services for the intensive maintenance. Lawns fail to provide some culture services because of their limited accessibility and symbolism of Western culture. Pollination services can be provided if certain spontaneous native plant species are allowed to flower. Concrete suggestions for SLTs in China were proposed, although challenges that impinge the transition to SLTs were identified. Meanwhile, current social-cultural, environmental and economic conditions in China encourage their implementation.

The thesis contributes to knowledge that addresses the mismatch between perceived and actual ecosystem services provided by lawns. The results can be used as references for design and management of SLTs in practice.

Keywords: urban green spaces, lawn, sustainable lawn alternatives, biodiversity, ecosystem services, social perception

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Att ompröva gräsmattor som dominerande inslag i urbana grönområden. Att utforska hållbara gräsmattealternativ utifrån sociokulturella och ekologiska perspektiv i kinesiska storstäder

Sammanfattning

Gräsmattan är ett av de mest synliga elementen inom urbana grönområden och västerländsk landskapsstil. Kina har sett en dramatisk ökning av anlagda gräsmattor. Det finns dock ett akut behov av hållbara alternativa gräsytor (SLT) i Kina på grund av de allvarliga hot mot stadsmiljön som den intensiva skötseln och den brist på kulturell anpassning som utbredningen av gräsmattor innebär. Denna avhandling försöker undersöka orsakssamband utifrån en historisk kontext och dagens situation avseende gräsmattor i Kina och ger förslag på SLT baserat på en fallstudie i Xi'an, i vilken ett tvärvetenskapligt ramverk tillämpats utifrån sociokulturella och ekologiska perspektiv.

En historisk studie angående orsaker till gräsmattans utveckling i kinesiska städer samt moderna europeiska och kinesiska exempel på alternativ till gräsmattor genomfördes genom litteraturstudier och fältobservationer. Därefter följde en studie med intervjuer, frågeformulär och observationer i syfte att utvärdera hur intressenter och parkbesökare uppfattar gräsmattor och hur detta påverkar deras beslut avseende utformning, underhåll samt användning av gräsmattor och alternativa gräsytor. För att identifiera hur utformning och underhåll påverkar mångfalden av växter och pollinerare, genomfördes inventeringar av biodiversitet. Slutligen analyserades resultaten av de tre studierna utifrån ett ramverk baserat på teorier om hållbara landskap och ekosystemtjänster.

Resultaten tyder på att människor i Kina och deras syn på gräsmattor har påverkats av västerlandet och globaliseringen efter 1840-talet. Gräsmattor utvecklas i relation till hur förhållandet mellan människor och deras miljö förändras. I klassiska kinesiska trädgårdar användes marktäckande arter i enlighet med deras ekologiska egenskaper och lämplighet för förhållandena på platsen. Gräsmattor i Xi'an har i huvudsak samma gräsarter som gräsmattor i geografiskt avlägsna områden, vilket bidrar till en homogenisering av arter i gräsmattor över hela världen. Intensiv skötsel påverkar mångfalden av växtarter och förekomsten av inhemska arter negativt, medan mer planerade grönområden samt äldre och större gräsmattor har en diversitet med avseende på växtarter med en förekomst av inhemska växter. Gräsmattornas estetiska värden och reglerande ekosystemtjänster uppskattas mest av parkbesökare och intressenter, även om en intensiv skötsel försämrar gräsmattors förmåga att tillhandahålla reglerande ekosystemtjänster. Gräsmattor lyckas inte tillhandahålla vissa kulturella ekosystemtjänster på grund av begränsad tillgänglighet och västerländsk symbolik. Pollineringstjänster kan erhållas om vissa spontant etablerade inhemska växtarter tillåts blomma. Konkreta förslag till SLT i Kina föreslås, även om utmaningar som påverkar övergången till SLT identifieras. Samtidigt främjas deras genomförande av nuvarande sociokulturella, miljömässiga och ekonomiska förhållanden i Kina.

Avhandlingen bidrar till kunskap som behandlar diskrepansen mellan upplevda och faktiska ekosystemtjänster som tillhandahålls av gräsmattor. Resultaten kan användas som referenser för utformning och underhåll av SLT i praktiken.

Nyckelord: urbana grönområden, hållbara alternativ till gräsmatta, biodiversitet, ekosystemtjänster, social uppfattning

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Dedication

This thesis is dedicated to my family.

谨以此文献给我的家人。

*We cannot fully understand, predict or control complex systems,
but we can envision, design and dance with them!*

Donella Meadows

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I would like to express my gratitude to my supervisors for supporting me in getting to this point. I would like to thank my main supervisor, Maria Ignatieva who offered me the precious opportunity to study in Sweden, introduced me to academic life in Landscape Architecture and helped me integrate background knowledge to the research. You are very knowledgeable and I am impressed by your enthusiasm towards your work. I appreciate the freedom you gave to me to pursue my interests. It was rewarding to work with you. I would like to thank my co-supervisors Anders Larsson, Karin Ahrné, Jörgen Wissman and Shuoxin Zhang. Anders, I appreciate the opportunity to teach in your course and your encouragement and thoughtful instructions on my kappa and papers. I would like to thank Karin and Jörgen very much for the meetings and discussions on the planning and writing of my papers and always being there to support me. I am very grateful for Professor Zhang's tremendous support and help during my master's period, in my PhD application and all the resources you provided me during my field work in China. I learned a lot from your academic and personal knowledge.

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Content

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I   Yang, F.-P., Ignatieva, M., Larsson, A., Xiu, N. & Zhang, S.-X. (2019). Historical Development and Practices of Lawns in China. *Environment and History*. DOI: https://doi.org/10.3197/096734018X15137949592098.

II   Yang, F.-P., Ignatieva, M. & Larsson, A. Public perceptions regarding lawns and their alternatives in China-a case study of Xi'an. *Manuscript*.

III Yang, F.-P., Ignatieva, M., Ahrné, K., Wissman, J., Zhang, S.-X. & Zhu, S.-Y. Relationships between multi-scale factors, plant and pollinator diversity, and composition of park lawns and other herbaceous vegetation in a fast growing Chinese mega-city. *Landscape and Urban Planning* (re-submitted after revision).

Paper I is reproduced with the permission of the publishers.

The contribution of Fengping Yang to the papers included in this thesis was as follows:

I   I developed the research design, the framework for assessing the literature and project documents and wrote the text. The co-authors assisted with the paper structure and discussion of findings.

II   I developed the research design. I collected the empirical materials, did the analysis and wrote the text. The co-authors helped with research design and discussion of findings.

III I planned the research design, collected empirical materials, did analysis and wrote the text. The co-authors helped with research design discussion of findings and text writing.

1   Introduction

1.1   Background

Globalisation and Westernisation (adaptation to Western culture) have driven the homogeneity of urban green spaces based on Western patterns worldwide. Today, lawn is one of the most common elements of urban green spaces in many cities worldwide (Ignatieva & Marcus, 2018). In some cities, lawns take up as much as 70% of urban green spaces (Ignatieva, 2011). In the UK, up to 60% of private gardens use the lawn as an essential element (Smith & Fellowes, 2014). The estimated total cover of lawns in Swedish cities is as much as 22.5% (Hedblom et al., 2017). Lawns can be found in the front- and backyards of private gardens, public parks, institutional green areas, golf courses and along streets and roads. If managed properly, lawns can provide crucially important ecosystem services in the urban context (Beard & Green, 1994), including water and nutrient management, carbon sequestration, maintaining biodiversity (Fuller et al., 2007) and contributing to human well-being in terms of aesthetic beauty, physical and mental health and recreation (Golubiewski, 2006; Gross et al., 1991; Mueller & Thompson, 2009; Raciti et al., 2008). However, improper design (monoculture) and intensive management (frequent mowing, irrigation, spreading of pesticides, herbicides and fertilisers) mainly for aesthetic reasons have led to serious threats to the urban environment (Robbins & Birkenholtz, 2003). Specifically, the intensively managed lawn is regarded as a biodiverse-poor community and has high global warming potential by emitting greenhouse gases from maintenance practices (Gu et al., 2015; Smith & Fellowes, 2014). Pesticides, herbicides and chemical fertilisers as non-point source pollutions of water have become increasing concerns in recent years and can cause negative impacts to people's health (Hernke & Podein, 2011; Zhou et al., 2008). Water for irrigating turf grasses can take up 30% to 60% of municipal potable water (Simmons et al.,

2011). Having recognised those problems, researchers in the USA (Simmons et al., 2011; Byrne, 2005; Robbins, 2012), New Zealand (Stewart et al., 2009), the UK (Smith & Fellowes, 2013-2014), Sweden (Ignatieva et al., 2015) and France (Bertoncini et al., 2012) started to question the lawn phenomenon and propose lawn alternatives, which are more sustainable and environmentally friendly compared with conventional lawns. However, it is still a poorly studied urban phenomenon, especially in late adopters of lawns, such as China.

The lawn is an essential element of European Renaissance-Baroque-Picturesque-Gardenesque and Modernist style landscapes (Ignatieva & Ahrné, 2013) and can be regarded as a symbol of Western culture. Nevertheless, it is widely introduced to geographically and culturally distinct regions from Europe, such as the USA, New Zealand, Chile, Australia and even China, even though China is one of the biggest eastern countries, which has a distinct culture compared with the Western countries. From 1997 to 2016 the planted area of lawns in China increased dramatically from 9210.53 hectares to around 50000 hectares (Figure 1). Meanwhile, China, as the most populous and largest developing country in the world, has been urbanising at a rapid speed during the past three decades (Wang et al., 2007). The frequent trade and communication after the Open Door policy in 1978 enhanced the influence of Western culture and related Western landscape design. Driven by the rapid development of China, and the influence of colonial culture, globalisation and Westernisation processes, the lawn as a representative of Western landscape styles was introduced and has become prevalent in China despite of geographical or climatic differences and local cultural peculiarities. Therefore, it is important to obtain knowledge about how the lawn is adapted to the local cultural environments in China.

Additionally, the lawn is an ecological phenomenon. The lawn as a prevalent element of Western landscapes and its related planting and management regimes and seed mixtures were imported to China. China is one of the mega-diversity countries having abundant biodiversity resources (Wang et al., 2007). However, the rapid urbanisation and the related land use change as well as human disturbances have threatened China's biodiversity and caused a biotic homogenisation and invasion of exotic species (Yang et al., 2016). Whether the planting and management regimes of lawns can be seen as human disturbances contributing to the biotic homogenisation and species invasion in China needs to be explored.

At present, China is facing serious environmental problems. About 70% of the surface water and more than half of the underground water in urban areas has been contaminated. Around 10,000,000 hectares of farmland have been contaminated by heavy metals and farming chemicals; hundreds of plant and

animal species are under threat (Saunders, 2013). It is urgent to find sustainable solutions to these environmental problems. Building green spaces is one of the strategies driven by Chinese environmental policy (Sze, 2015). However, the lawn, which was regarded as an efficient way of building green areas, risks causing problems to the already seriously threatened environment because of its intensive management practices and monoculture planting regime. The increasing area of planted lawns in China and the negative effects of lawns on the urban environment cannot be neglected; actions need to be taken to solve the problems related to lawn use.

Yearly Planted area

Unit: hectare
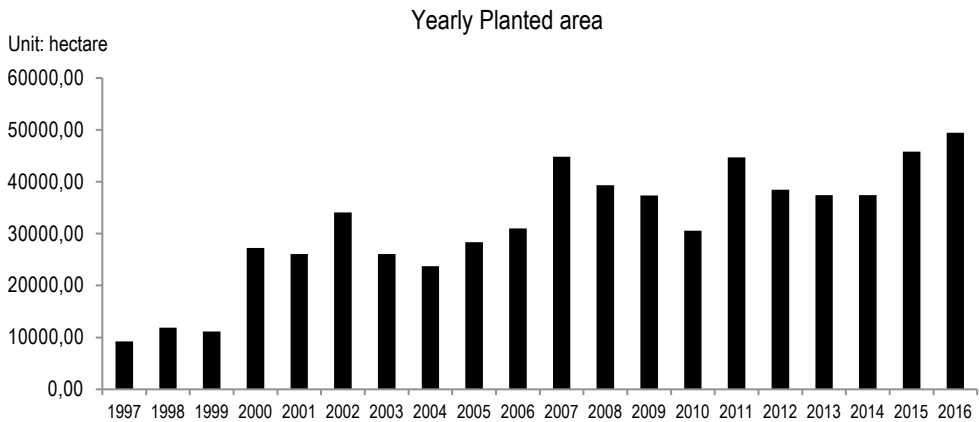
Figure 1. Yearly planted area of lawns in China from 1997 to 2016 (Ministry of Agriculture of PRC, 2017).

1.2 Personal background

While I was studying as an undergraduate student in landscape architecture in China, I received a systematic education in Classical Chinese Gardening (CCG). The principles of CCG (*i.e.* unity of human and nature; although the garden is man-made, it should appear natural) have been imprinted in my mind. However, these principles have been neglected in the contemporary landscape design in China. Instead, the landscapes inspired from European Renaissance-Baroque-Picturesque-Gardenesque and Modernist style which originated from Western countries, are prevalent in Chinese cities driven by the trend of Westernisation and globalisation (Yu & Padua, 2007). The well-mown lawns, together with huge plazas, peaceful lakes, scattered broad-leaved trees and regular annual flower beds became a symbol of a globalised landscape (Chen, 2013). This aroused my interest in the influence and adaptability of

Western landscape design in Chinese contemporary landscapes. Furthermore, the project "Lawn as Ecological and Cultural Phenomenon" led by my supervisor, Maria Ignatieva, inspired me to focus on the lawn as a common element of Western landscape styles. My study and personal background in China give me an impression of lawn prevalence in public parks of China. However, when and why lawns were started to be used in public parks and what existed before lawn use in public parks and classical Chinese gardens aroused my curiosity. Apart from that, the potential environmental problems caused by the lawn worried me because of the already heavily contaminated environment in China. I feel a sense of responsibility, as a landscape architect in China, to find alternatives to lawns. Furthermore, my master degree research in ecology has aroused my interest in ecosystems. I later found that the urban ecosystem is far more complicated than the forest ecosystem which I studied during my master's thesis. The urban ecosystem is not only impacted by the natural conditions but also affected by human interferences. This is especially obvious for lawns as they are the most common human-created and culture-shaped urban habitat (Byrne, 2005). Therefore, I started my PhD research by studying lawns as an example of Western landscape styles to evaluate the impacts and adaptability to the Chinese environment, as well as search for alternatives.

1.3 Research aims and questions

1.3.1 Research aims

This study aims to investigate the phenomenon of lawns in China and examine the reasons behind their rapid development and current design and management in Chinese cities from social-cultural and ecological perspectives. The main objective of this research is to find pathways to transition to sustainable lawn alternatives through theoretical and practical exploration. The definition of lawn and sustainable lawn alternatives will be elaborated in the theoretical part of this thesis (Chapter 2). Therefore, it is of great importance to obtain a comprehensive understanding of the environmental impacts of lawns, specifically on bio-diversity. It is also crucial to understand public opinion about and the historical and contemporary motives for the planning and management of different types of lawns in China, as one of the latest adopters of lawns. This is a fundamental empirical work, where I elaborate the lawn phenomenon from an inter-disciplinary perspective in order to better understand its implications in China. This work also aims to provide a baseline for further in-depth research and decisions to be taken by local practitioners and politicians.

1.3.2 Research questions

The research questions (RQ) and secondary research questions and the relevant aims are summarized in Table 1.

Table 1. Summary of research aims, research questions (RQ) and secondary-RQ.

Aim	Research questions	Secondary-RQ
1. To examine the reasons behind the origin, historical development, current design and management practice of lawns in China	What are the historical context and current situation regarding lawns in China?	What are the drivers behind the historical development and current practices of lawn design and management in China?
		What is the plant species diversity and composition of lawns and the influential factors in Xi'an?
		What ecosystem services are provided by the lawn and what factors influence the provision of ecosystem services in Xi'an and China?
2. To offer suggestions for sustainable alternatives to the existing lawn design and management, which would fit into the local context	How could the transition from current lawns to sustainable alternatives be achieved in a Chinese context?	Which implications for future sustainable lawn alternatives in Xi'an and China can be drawn and developed from this study?
		What are the challenges of changing current lawn design and management in Xi'an and China?
		What opportunities are there for implementing sustainable lawn alternatives in the future in Xi'an and China?

1.4 Thesis structure

This thesis consists of five chapters and three appended papers. Chapter 1 provides a general introduction to the research topic: the initial problem statements and the research focus as well as the aims and research questions of the thesis. In Chapter 2 the theoretical and conceptual context for this thesis are presented, while Chapter 3 gives a detailed explanation of the research strategy and methods. Chapter 4 provides an overview of Papers I-III and presents the

main findings and how the papers relate to each other in relation to the research question. Finally, in Chapter 5 the results of the study based on the research questions and the theoretical contribution of this PhD work are discussed and future research is proposed.

2 Theoretical and conceptual context

This chapter provides a description of some of the relevant definitions, theories and problems related to urban green spaces, lawns and their alternatives. It further reviews the theories and concepts of landscape sustainability, ecosystem services and urban ecology, which establish a theoretical basis for the transdisciplinary research for understanding Chinese lawns and searching for sustainable lawn alternatives. Urban biodiversity and social perceptions of urban green spaces (UGSs) are the main perspectives taken in researching the lawn phenomenon. The reasons why these perspectives are chosen are explained by presenting their importance and some key concepts. The theoretical framework of my research is presented in Figure 2. The specific criteria selected for analysing the sustainability of lawns and its alternatives are presented in Figure 3.
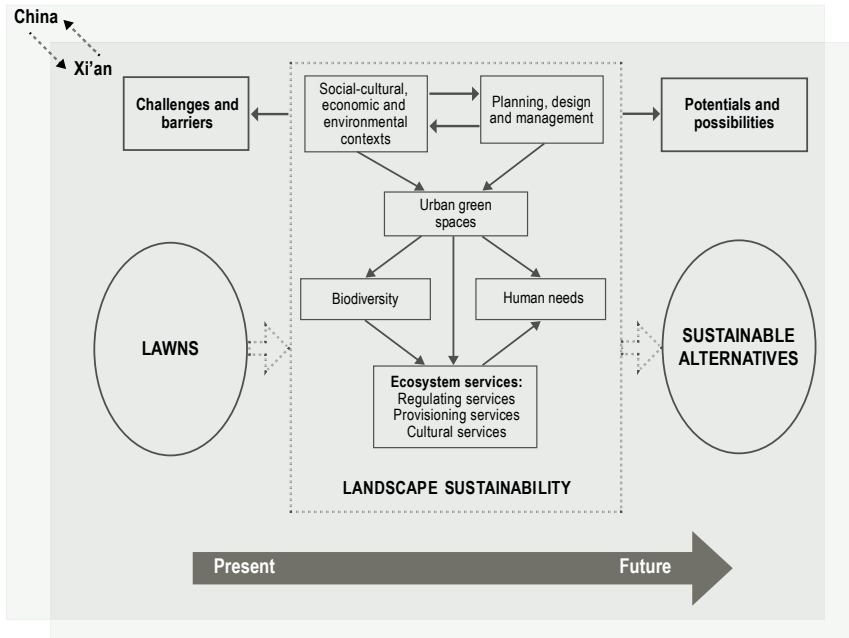
Figure 2. Theoretical framework of the thesis. Modified based on the framework for landscape sustainability science (Wu, 2013)

Landscape sustainability
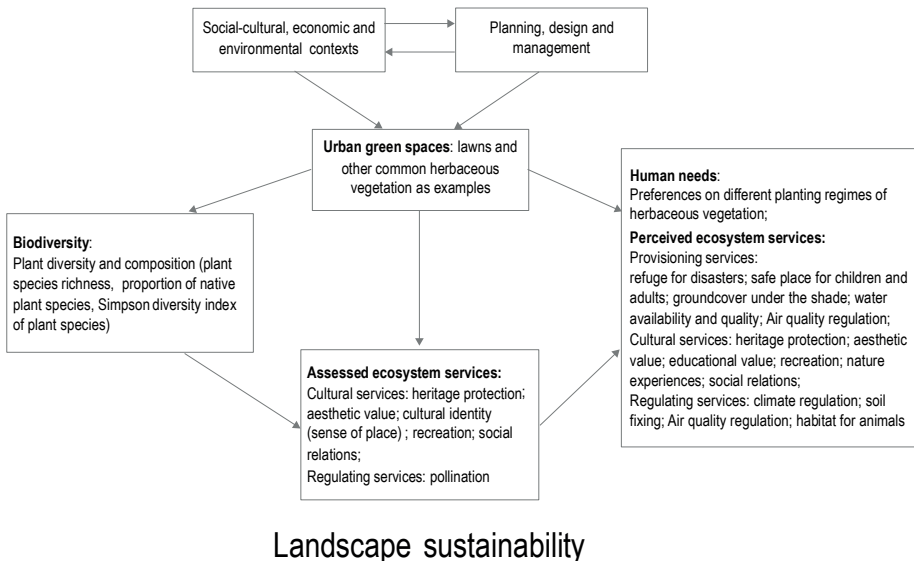
Figure 3. The specific criteria selected in this thesis for assessing and analysing sustainability of lawns and its alternatives.

2.1 Sustainable landscape

Sustainability has become an increasingly important goal in landscape architecture research and practice (Ahern, 2006; Chen & Wu, 2009). According to the definition in the World Commission on Environment and Development (WCED) (1987, p. 24), sustainability refers to sustainable development "that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainability science is a trans-disciplinary field emphasising the understanding of dynamic human-nature relationships (Kates et al., 2001).

According to the American Society of Landscape Architects (ASLA) (ASLA, 2017), "Sustainable landscapes are responsive to the environment, re-generative, and can actively contribute to the development of healthy communities. Sustainable landscapes sequester carbon, clean the air and water, increase energy efficiency, restore habitats, and create value through significant economic, social and, environmental benefits".

A number of definitions of landscape sustainability or sustainable landscapes focus on natural capital and ecosystem services. For example, Potschin and Haines-Young (2006, p.167) claim that "a sustainable landscape is one in which the output of ecosystem goods and services is maintained, and the capacity of those systems to deliver benefits for future generations is not undermined…''. Wu (2013, p. 999) defines landscape sustainability as "the capacity of a landscape to consistently provide long-term, landscape-specific ecosystem services essential for maintaining and improving human well-being". Nassauer and Opdam (2008) confirms the importance of landscapes in sustainably providing ecosystem services while recognisably meeting societal needs and respecting societal value. The landscape design is vital for making changes in landscape patterns that facilitate the provision of a landscape's ecosystem services (Nassauer & Opdam, 2008). The theoretical framework used in this thesis was adjusted from Wu's definition of landscape sustainability which is based on a review of a large number of previous works (Figure 2).

One interesting and important concept proposed by Chen and Wu (2009) is that the Chinese ancient philosophy of the unity of human and nature and its corresponding design principles could provide guidelines for the development of sustainable landscape architecture. The philosophies of Daoism, Confucianism and Buddhism are the main streams of Chinese traditional ideologies and have profound influences on the ideals and practices of Chinese landscape architecture (Zhou, 2008). Unity of man with nature or harmony between man and nature (*Tian Ren He Yi*) is one of the main principles in Chinese philosophies. It asserts that humans should harmonise with the

rhythms of nature (Li & Qiu, 2013). The corresponding principle of Chinese classical gardens, from nature but beyond nature, emphasises that landscape design should follow and utilise the natural order and address ecological principles of a specific location, while modification could be applied to nature by incorporating artificial elements to meet the social, economic, and cultural needs of humans who interact with the landscape. Sustainable landscape architecture in China can be seen as a hybrid of modern theories of sustain-ability and the ancient garden principle unity of man with nature. Therefore, the philosophical root of unity of man with nature in Chinese society facilitates the achievement of sustainable landscape architecture and inspires the design of sustainable lawn alternatives in China. These concepts will be discussed later in this thesis and explained in detail in the historical study of lawns in China (Paper I).

Despite of the different definitions on the landscape sustainability, there is a consensus that protecting the earth's life support system is vital for achieving the ultimate goal of sustainability of improving and maintaining human well-being (Wu, 2013). Both Levin (2012) and Perrings (2007) claim that the core of sustainability is provision of ecosystem services. Similar ideas have been proposed in the 1987 Brundtland Report (WCED 1987), the 1999 United States National Research Council report (NRC 1999), and the 2005 Millennium Ecosystem Assessment (MEA, 2005) report.

2.1.1 Ecosystem services

Ecosystem services are the benefits that human beings gain from ecosystem functions (De Groot et al., 2003; MEA, 2005). Urban ecosystem services refer to the services provided by urban ecosystems and their components. All green and blue spaces in urban areas, such as parks, cemeteries, yards and gardens, urban allotments, urban forests, wetlands, rivers, lakes, and ponds are important components of urban ecosystems (Gómez-Baggethun & Barton, 2013).

The importance of ecosystem services (ES) provided by the natural landscape (food, fibre, clean air and water) are recognised for meeting the basic needs of a growing global population. Accordingly, the analysis of ecosystem services has aroused the interest of researchers since the1960s, as a means of achieving sustainable development. The framework of describing and valuing ES is provided in several studies (Costanza et al., 1997; De Groot et al., 2003; MEA, 2005).

According to the Millennium Ecosystem Assessment (MEA) (2005), ecosystem services are classified into four broad categories: provisioning,

regulating, cultural and supporting services. Provisioning services are the products obtained from ecosystems, e.g., food, fibre and fresh water. Regulating services are the benefits obtained from regulation of ecosystem processes, e.g., air quality regulation, climate regulation and water purification and waste treatment, pollination. Cultural services are nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, e.g., cultural diversity, aesthetic values and recreation. Supporting services are those that are necessary for the production of all other ecosystem services, e.g., soil formation, photosynthesis, primary production and nutrient cycling. In the thesis, the focuses are provisioning, cultural and regulating services. Supporting services are not included as they are not used directly by people.

Most of the studies on urban ecosystem services focus on a single UES. Regulating services are the most commonly assessed services, followed by supporting services, cultural services and provisioning services (Haase et al., 2014). Only a few studies explore more than one dimension of UES (Morani et al., 2011). Furthermore, there is a lack of communication between stakeholders in the ecosystem services research, despite their importance in deciding the implementation of the results of the research (Haase et al., 2014). Previous studies have emphasized the importance of understanding how people perceive and use ecosystem services in informing and mediating people's responses to ecosystem management and policy (Asah et al., 2014). There are also limited studies explaining the relationship between ecosystem services and human needs (Ahammad et al., 2019). Understanding people's perception on ecosystem services is vital for implementing ecosystem management and policies which satisfies human needs and at the same time avoiding conflicts over the implementation of new plans and policies.

2.1.2 Urban green spaces as providers of ecosystem services

Urban green spaces are the major providers of ecosystem services (Breuste et al., 2013), and can be defined as the public and private open spaces in urban areas, mainly covered by vegetation that is either cultivated, the remnants of natural vegetation or greenery that has spontaneously appeared, (e.g. urban forests, single trees in streets and gardens, lawns, shrub plantings, flower beds and other ornamental plant arrangements) (Breuste et al., 2013; Haq, 2011). Public green spaces include parks and nature reserves, sport fields, riparian areas, like stream and river banks, greenways and trails, community gardens, street trees, as well as less conventional spaces such as green walls, green alleyways, cemeteries and even wastelands. Private green spaces refer to

private front yards and backyards, communal grounds of apartment buildings, and corporate campuses (Wolch et al., 2014). Urban green spaces expose urban residents to nature as well as provide other ecosystem services. For example, they could maintain urban biodiversity, reduce environmental hazards, such as air pollution or noise, mitigate the impacts of extreme weather events, enhance the quality of urban living and improve the health and well-being of residents.

As introduced in section 1.1, lawns are one of the most commonly used elements in all types of urban green spaces today. In this thesis the lawn is defined as artificially created, modified European natural grasslands where only certain grass species were chosen and frequently maintained to achieve the appearance of smooth green carpet.

In this study sustainable lawn alternatives include both alternatives to lawns and alternatives of lawns. Based on the review of sustainable landscapes and the context of lawns, sustainable alternatives to lawns are defined as sustainable alternatives to lawns as landscapes that are biodiverse (both grasses and forbs) and have the capacity to provide ecosystem services essential for human needs in the long term. Furthermore, sustainable alternatives of lawns are defined as biodiverse lawns which are polyculture of grass species and can provide ecosystem services essential for human needs in the long term. In this thesis, the main focus will be regarding sustainable alternatives to lawns. In order to provide ecosystem services for human needs both now and in the future, humans should harmonise with the rhythm of nature. Therefore, in order to realise the transition from lawns to sustainable alternatives, an assessment of lawns' historical context and current situations and associated biodiversity and ecosystem services, together with factors hindering or helping the provision of ecosystem services of lawns, needs to be studied. One of the main questions, in this regard, is how the planning, design and management of lawns can be adjusted to enhance biodiversity and provide ecosystem services to address social needs and values.

2.2 Interdisciplinary approach towards sustainable urban green spaces based on urban ecology principles

Urban ecology assists in understanding how city dwellers can interact with and benefit from urban green spaces (Niemelä, 2014).

Urbanisation results in an increasing proportion of the population living in cities. More than 50% of the world's population now live in cities (Population Division, 2012). In Europe it is expected that around three quarters of the population will live in urban settings by 2020 (WHO/Europe, 2017). In China, for the first time in 2010, the urban population exceeded the rural population

(Wu et al., 2014). The rapid urbanisation process has resulted in many environmental, economic and social problems, which need to be understood and resolved. In order to achieve a sustainable urban future, how urban ecosystems currently work and how they ought to work must be understood. Urban ecology and related sustainable strategies are essential for understanding the urban environment (Wu, 2014).

Urban ecosystems are complex socio-ecological entities (Folke et al., 2011). Urban ecology is an evolving discipline, integrating both basic and applied natural and social science research into urban ecosystems (Mcdonnel, 2011). It has developed from research about ecology in cities or the ecology of cities into the "sustainability of cities". In 1920, sociologists initiated the use of the concept and theory of ecology in the study of the human-related urban environment, which is an important subdivision of human ecology. However, during the first half of the twentieth century the ecology in cities was largely ignored by ecologists (Grimm et al., 2008). Around the 1960s, the Berlin School placed an emphasis on the ecology in cities with the exception of human beings (Sukopp & Hejný, 1990). After 1995, urban ecology began to shift from empirical research of urban ecosystem patterns to understanding how multiple physical, social and biological components interact and form urban ecosystems and how the results can be connected to urban planning and management (Douglas, 2012). According to Wu (2014), transdisciplinary research is a recent trend in the field of urban ecology, setting sustainability oriented goals, applying methods from both natural and social sciences and involving multiple participants (scientists, practitioners, decision makers, and varied stakeholders). Based on his previous works, Wu (2014) proposed the "sustainability of cities" as a new category of urban ecology. He defines it as "an adaptive process of facilitating and maintaining a virtuous cycle between ecosystem services and human well-being through concerted ecological, economic, and social actions in response to changes within and beyond the urban landscape" (Wu, 2014). Other authors emphasise the importance of holistic research in urban ecology suggesting that the concepts in natural sciences and social sciences be combined to evaluate how urban ecosystems are influenced by biophysical and social factors (Alberti, 2008; Folke et al., 2011).

2.2.1 Ecological perspective: urban biodiversity

Biodiversity and the interaction between organisms and links to human activities are the focus of urban ecology (Guntenspergen et al., 2011). Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part" (Magurran, 2013).

Urbanisation is a great threat to urban biodiversity. However, cities can play a vital role in conserving biodiversity through planning and managing urban green spaces (Ives et al., 2016).

Biodiversity in urban areas is distinctive from that in other landscapes because of unique physical and ecological condition as well as various and continuous influences from human beings (Müller & Werner, 2010). Conserving urban biodiversity has multiple benefits. It can help preserve important local biodiversity in an urbanising environment, create stepping stones or corridors for natural populations, facilitate species' responses to environmental change, connect people with nature, provide opportunities for environmental education, provide ecosystem services, fulfil ethical responsibilities and improve human well-being (Dearborn & Kark, 2010; Ossola, et al., 2018). Understanding the drivers of biodiversity in urban green spaces is valuable for global biodiversity conservation (Aronson et al., 2017; Müller & Werner, 2010).

Biodiversity can be dissected into three components: genetic diversity (within-species diversity), species diversity (number of species) and ecological diversity (diversity of communities). Because species is the common currency of diversity, species diversity was studied in this research (Magurran, 2013). More specifically, pollinators and higher vascular plant species in urban lawns are my focuses.

Previous studies have indicated that the floristic diversity and plant species composition of lawns are linked to the degree of urbanisation, location, management intensity and other local environmental factors (Bertoncini et al., 2012; Loram et al., 2008; Pal et al., 2013; Thompson et al., 2004). For example, it was found that plant diversity of lawns in Paris was significantly influenced by factors such as mowing frequency, type of ownership, use of pesticides and public access (Bertoncini et al., 2012). Similarly, a study in Christchurch, New Zealand found that maintenance activities played a significant role in explaining variations in the species composition of lawns (Stewart et al., 2009). A study in Santiago de Chile found that the biodiversity patterns of lawns are strongly influenced by maintenance intensity (Fischer et al., 2016). However, in Sheffield, UK, species composition was significantly influenced by the local climate (Thompson et al., 2004). In summary, the factors that explain the variations in the biodiversity patterns of lawns differ depending on local peculiarities.

Insect pollinators such as bees, wasps, flies and butterflies are crucial for plant reproduction, human food security and health, as well as ecosystem functions (Kearns et al., 1998; Vanbergen & Initiative, 2013). Evidence shows a recent global decline in pollinators and the plants that depend upon them

(Goulson et al., 2015; Potts et al., 2010), including in China (Teichroew et al., 2017). Urbanisation contributes to declining pollinator populations by destroying and fragmenting the natural habitats of many pollinators (Vanbergen & Initiative, 2013). There are also many other contributors to pollinator decline, such as the use of chemicals and lack of flowers (Goulson et al., 2015). The diversity of pollinating insects that are dependent on plants for different stages of their development is often related to a high diversity of plants (Goulson et al., 2015; Potts et al., 2010). However, few studies have been conducted on the pollinators associated with spontaneously occurring flowering herbs (usually regarded as weeds) in lawns (Larson et al., 2014). An inventory of these pollinators and their interactions with plant diversity in lawns could help foster a paradigm shift to pollinator-friendly lawn design and management practices in urban areas.

2.2.2 Social-cultural perspective

Urban green spaces (UGS) offer possibilities for renewal, physical activity, social interaction and community attachment. There is an increasing interest in how humans perceive urban nature (Haaland & van den Bosch, 2015). A key challenge for UGS conservation, design, and management is balancing human perceptions, needs, and use with ecological requirements for preserving and enhancing biodiversity (Aronson et al., 2017).

Perception is an active process occurring between the organism and environ-ment. During this process, information is obtained through the senses, organised and interpreted (Kaplan & Kaplan, 1978). Landscape perception is expressed in terms of complexity and mystery, which is associated with the need to gather information and the coherence and legibility associated with the need to understand information (Kaplan & Kaplan, 1989).

Perception of the environment or landscape may affect user behaviour and reflect user motivation, preferences and attitudes, which could provide practical information on design and management of UGSs (Gunnarsson et al., 2017; Jim & Shan, 2013). Previous studies have revealed that users showed various and complex perceptions and preferences of UGSs, nature and biodiversity.

Research in Guangzhou found a widespread recognition of ecosystem services and strong support of UGS programmes among residents (Jim & Chen, 2006). Tranquillity, the feeling of being in a forest and naturalness are values of urban woodlands that are recognised and favoured by local residents in Helsinki (Tyrväinen et al., 2007). However, studies in the UK and Italy showed that certain groups of people such as women, children and the elderly perceive UGSs negatively and tend to associate them with crime and feelings

of being unsafe (Burgess, 2002; Nayak, 2003; Sanesi & Chiarello, 2006). People who are negative to UGSs tend to avoid them and adjust their use pattern (Bixler & Floyd, 1997; Crewe, 2001; Westover, 1985). However, those who value and feel positive towards UGSs are more likely to use them actively and benefit from UGSs (Ward Thompson et al., 2005). Therefore, it is important to understand the perception of urban green spaces among social groups in different cultures and backgrounds to provide suggestions for UGS design and management and maximise the benefits of UGSs.

Perception of nature

Urban green spaces are regarded as urban nature that fulfils several functions for the urban population (Unterweger et al., 2017). Additionally, UGSs make it possible for local residents to connect with nature. Therefore, local residents' perception of nature may mirror their preferences and attitudes towards urban green spaces.

People often show a higher preference for scenes dominated by natural features (e.g. trees, water and grasses) compared to scenes of urban areas without such natural features (Hartig & Staats, 2005; Home et al., 2010). An insignificant but positive relationship was reported between naturalness and landscape preferences (Kaplan et al., 1989). A study in Netherlands found that most of the respondents prefer the landscape in which one may experience the greatness and forces of nature. It is connected to the respondents' high ascription of naturalness to penetrative nature (De Groot & Van den Born, 2003).

Nevertheless, those who have high fear expectations, disgust sensitivity and a desire for modern comfort, tend to prefer a manicured park environment and do not like the wild environment (Bixler & Floyd, 1997). In the USA, regular mowing of grassy areas and pruning of larger plants were applied by the landowners as "cues to care" for their property, which are also suggested in the design for framing the natural and messy ecosystems (Nassauer, 1995). Americans were suggested to appreciate the 18th century picturesque nature, which resulted in a preference for tended and neat spaces rather than wild landscapes (Williams & Cary, 2002). Gobster (1994) found that children's preference for savanna decreased as naturalness increased when studying the public perception of natural savanna restoration in urban areas of the Chicago area.

Perceptions of urban nature also vary with personal, social and cultural reasons. Some people in Sheffield, UK found that naturalistic landscapes to be a place in which they could better experience the sense of naturalness and the feeling of freedom, while other people felt that they were safer in a formal landscape setting and found it more peaceful and quiet, more calming than naturalistic landscapes (Özgüner & Kendle, 2006). Buijs et al. (2009) found

that the native Dutch showed a higher preference to wild and unmanaged landscapes than immigrants, indicating that the two social groups perceived nature differently. Moreover, in the USA students' preferences for natural and wild areas over clean and neat residential landscapes are related to numerous variables including the disciplines they engaged, place of residence, environmental attitudes and their parents' education levels (Zheng et al., 2011). In the Netherlands, personal traits, (e.g., personal needs structure) are indicated to be relevant to gardeners' ownership of a manicured or romantic garden instead of a wild and natural garden (van den Berg & van Winsum-Westra, 2010). Therefore, people's perception on urban nature is context related and could be affected by a variety of factors. Understanding the reasons of people's various perceptions on nature are essential for designing urban green spaces which provides nature experiences for a majority of people.

Perception of biodiversity of UGSs

Research shows that people, in general, express positive attitudes towards biodiversity of UGSs. For example, Lindemann-Matthies et al. (2010) found that plant diversity was attractive to humans and monoculture grasslands dominated landscapes are less attractive for local residents due to a reduction of diversity caused by intense management. The research of Carrus et al. (2015) demonstrates the positive role of biodiversity upon perceived restorative properties and self-reported benefits for urban and peri-urban green spaces (Carrus et al., 2015). Moreover, human well-being is suggested to have a positive relationship with biodiversity and its relevant indicators, (e.g., species richness and abundance of birds) (Dallimer et al., 2012; Fuller et al., 2007; Luck et al., 2011). Research confirmed the UGSs users' ability to perceive species richness and biodiversity differences (Fuller et al., 2007; Qiu et al., 2013).

However, complex results were found in people's perceptions of bio-diversity. Perceptions of biodiversity differ with the occupational backgrounds of respondents. For example, farmers' perceived biodiversity is different from that of residents and visitors (van den Berg et al., 1998). In Germany, landscape planners favour very natural areas with low accessibility and high species richness, while the residents preferred less species-rich formal parks (Hofmann et al., 2012). Distinct preferences of different groups of organisms are also demonstrated in some research. Respondents showed a strong preference for gardens rich in plant species but disliked the insect diversity (Shwartz et al., 2014). Conservation of songbird diversity in urban habitats is suggested because of people's appreciation of bird song diversity in urban areas (Hedblom et al., 2014).

People's perception of urban green spaces, urban nature and urban bio-diversity are very complex. Thorough case studies are needed in order to provide suggestions for local urban green space design and management for different contexts, as well as research on universal patterns of people-biodiversity interface in cities (Botzat et al., 2016).

Perception on lawn

Lawns are seen as a recent social and cultural phenomenon and a symbol of globalisation and the market economy (Ignatieva et al., 2017). Several studies in different regions have found different reasons of use of lawns and its alternatives. Kaufman and Lohr (2002) find that environmental attitudes and concerns over the time and expense of maintaining a lawn determine private garden owners' choices on vegetation types other than lawns in the USA. However, individual interests and social pressures are found as reasons why people in the USA decide to apply fertilisers to lawns in their yards (Carrico et al., 2013). In addition, a study in Canadian cities shows that the pesticide-free yard care practices and divergent lawn aesthetics determines the residents' pesticide policy preferences (Hirsch & Baxter, 2009). Environmental knowledge, functionality of native vegetation and social norms that value pro-environmental and native gardening behaviour are identified as drivers of residents' decision to change from lawn-dominated garden styles to native gardens in Western Australia (Uren et al., 2015).

The public perception and preferences of lawns alternatives are complicated and vary with multiple factors in different countries. In the USA, Yue et al. (2012) identify a strong consumer preference for reduced irrigation and mowing requirements of lawns, which confirms that low-input turf grasses could be a viable strategy for reducing the maintenance inputs and costs for residential lawn care. Perennial meadows were proposed by British scholars as an alternative to lawns. Such landscapes use a mixture of native and exotic perennial plants to replicate the appearance of wild meadows (Hitchmough & Fleur, 2006; Southon et al., 2017). Surveys of green space visitors' preferences in Northern England indicate higher preferences for perennial meadows compared to lawns, although frequent visitors show lower preference to perennial meadows due to a strong attachment to the site (Southon et al., 2017). Research on land managers' perceptions find that feasibility of future urban meadow establishment in British cities is context-related and impacted by factors including aesthetics and public reaction, locational context and human resources, as well as economic sustainability (Hoyle et al., 2017). However, the findings of the research on public perception and preferences for perennial wildflower meadows (a type of meadow similar to those in used in

British cities) in Beijing, indicate that compared to the UK such meadows had a less positive reaction from university landscape students and non-professionals because of the public's different aesthetic expectation of Chinese green spaces (Jiang & Yuan, 2017). In the US, the public is also averse to the less-manicured aesthetics of native meadows because of a lack of awareness of the inherent values in sustainably managed roadsides (Lucey & Barton, 2011). Therefore, more research is needed, especially in countries that are late to adopt lawns, such as China, who has a very distinct culture from that of Western countries. The public perception on lawns and its alternatives is of great importance for designing sustainable lawn alternatives which meet the needs of different social groups.

Moreover, to achieve comprehensive planning and management of lawns, better coordination within local government organisations and improved communication between various stakeholders, (e.g. urban planners, landscape architects, park managers) is required (Aronson et al., 2017). Despite all of this, most research focuses on local residents' and park visitors' perceptions. Only a few studies focus on the challenges and opportunities of lawns and their alternatives as perceived by stakeholders, although stakeholders are very decisive on the planning and management of lawns (Hoyle et al., 2017; Ignatieva et al., 2017). Case studies are required to explore the factors impacting stakeholders' views on lawn use and shift their paradigms for designing and managing lawns and developing sustainable alternatives.

3 Methodology

This chapter describes the research process behind this thesis work and the specific methods applied. It records the progress of the work and illustrates how this thesis was formulated (Figure 4).

3.1 Research strategy

The overall aim of the thesis is to explore the reasons behind the origin, development, current design and management of lawns in China. Furthermore, suggestions will be offered for sustainable alternatives to the existing lawn design and management by exploring results of ecological and sociological studies and fitting them into the local context. Therefore, lawns and their alternatives are the main topic of my PhD thesis.

Within landscape architecture, the relationship between research and design are classified as "research on design", "research for design" and "research through design". My research falls into the category of "research for design". This type of research supports the design process or design product, which requires a very wide knowledge base, ranging from the natural sciences and social sciences to the arts and humanities (Van den Brink et al., 2016b). My research offers suggestions for alternative solutions to current lawn design and management through investigation and the knowledge obtainment of the lawn phenomenon in Chinese cities. Knowledge for a meaningful design guideline will be obtained for practitioners. Research for design can be regarded as the creation of substantive knowledge through the generation of scientific data for future application (Van den Brink et al., 2016b). In order to obtain the knowledge of the application of possible lawn alternatives for my study, methodologies from both natural science and social science were applied.

The PhD thesis starts with a historical review of the origin of lawns, development and practices in China. Based on the literature review, the lawn,

as a globalised landscape, is widely used all over the world. However, sustainable lawn alternatives are context related. In order to search for sustainable lawn alternatives in Chinese cities, a case study was needed to test my methodology. The next step was selecting cases and designing my research based on the literature review and discussion with supervisors and colleagues. The process included a lot of meetings, courses, conferences and discussions. Based on the selected case study, the public perceptions of lawns and their alternatives were evaluated through questionnaire surveys, semi-structured interviews and observational studies. After that, how the perception of stakeholders and park visitors affect their decisions on designing, managing and using lawns were analysed. Later, how social-economic conditions influence the biodiversity (pollinator and plant diversity) of lawns and their alternatives were analysed. Implications of sustainable alternatives were developed based on those analyses about the context of lawns.
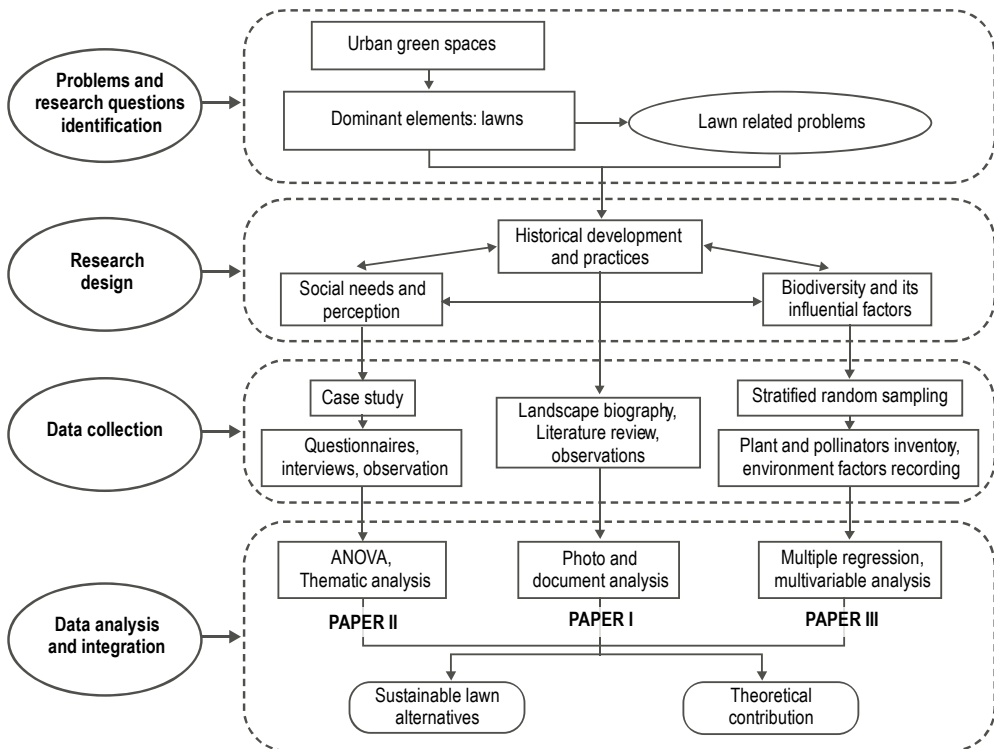
Figure 4. Overall research strategy performed in this thesis

3.2 Transdisciplinary methods

The research in urban ecology has become increasingly transdisciplinary by applying methods both in natural and social sciences (Wu, 2014). Novel solutions to complex problems could be generated and insight beyond current borders could be achieved through synergistic and skilful combining of different disciplines (Knapp et al., 2015). Methods and concepts from natural and social sciences were combined in this study, since the lawn is the most common human-created and culture-shaped urban habitat as well as a socio-ecological system (Byrne, 2005). This thesis is an example of transdisciplinary research since it relies on the following disciplines: ecology, social science and humanities (history) and includes stakeholders' view as well. Paper I used methods from historical research. Paper II used the methods in social sciences and Paper III utilised the methods in biodiversity (ecology) research. The knowledge about their biodiversity as well as the motivations, actions and preferences of stakeholders and park visitors needed to be obtained in order to offer practical suggestions to increase the biodiversity of lawns and their alternatives. This approach has guided the choice of methods being used in the different studies. This study demonstrated how all different research methods can be interpreted and led to an understanding of modern Chinese lawns as ecological but at the same time a social-culturally driven phenomenon.

3.3 Historical perspective

Landscape history tells how and why the landscape developed (Marcucci, 2000). In practice and in research, landscape biography is applied as an approach that is often used to analyse and explore the history of a landscape. Landscape biographies are particularly useful in the context of future landscape changes, when there is a need to understand long-term landscape changes about historical narratives of space and location (Van den Brink et al., 2016b). One of the aims of my PhD thesis is to suggest how to transform the current lawn design and management practices in China, thus the landscape biography was a suitable approach to obtain knowledge about the long-term changes in lawn use. Studying the historical development and practices of lawns in China also helped me to reflect on the current lawn design and management and get inspiration for alternative solutions to lawns. Specific sets of places or particular ecosystems, buildings and landscape sections or types of transformations are usually the focus of landscape biographies. A varied set of historical, environmental and other sources can be used as data to inform the integrative, long-term perspective of landscape changes.

The first phase of my research focused on the historical aspect of the lawn phenomenon. Previous studies found that the lawns are modified European grasslands and originated from the UK (Smith & Fellowes, 2013; Woudstra & Hitchmough, 2000; Ignatieva et al., 2018). When and why people began to use lawns in public spaces and what existed in classical Chinese gardens before the lawn in public parks remains unknown. Thus I started to review literatures and historical documents. Photographs and notes taken during field investigation in historical sites (relics) (the classical Chinese gardens) and public parks offered complementary material for the historical study of lawns. Traces of lawn practices in Chinese history were taken from historical documents (poems, historical literature), paintings, literature and historical sites. Literature review and site observation were methods used to analyse the historical development and practices of lawns. Photographed lawn and groundcover sites were used for describing, comparing and analysing the lawn development.

Field investigation in different cities, including Suzhou (Classic Chinese gardens), Shanghai (villa gardens in the old foreign concessions, first public parks built for foreign residents), Xi'an (public parks built in different times after the Second World War) were conducted. The use of groundcovers and lawns in the selected sites were photographed. Suzhou was selected because it is famous for the well-preserved classical Chinese gardens built in the Ming period (1368-1644). At that time, 300 domestic gardens were built and several of them still exist, which could provide insight as to how the classical Chinese gardens looked like and how groundcovers were used (Goode, 2016). The villa gardens and first parks built for foreign residents in the old foreign concessions after 1840s in Shanghai were visited to observe how the lawn was used in those gardens and parks, since Shanghai is the biggest among the five treaty port cities. These cities were opened to foreign trade and residence in the mid-19th century due to pressure from powers such as Britain, France, Germany and the United States. Xi'an is one of the four most important old capitals in China and had many famous classical Chinese gardens. Shanglin Garden, one of the biggest royal gardens in Chinese history, was built in the third century BC and enlarged in the second century BC in Xi'an. The Tang Dynasty (618-907 AD) was called China's first golden age. There were eight imperial gardens in the capital Xi'an at that time. For example, Daming Palace and its associated royal gardens, which were 4.8 times bigger than the imperial place in Beijing, were built during the Tang Dynasty (Zhou, 2008). Although those gardens no longer exist, the historical relics remain; heritage parks were built on those sites to protect the relics and provide public recreational spaces. The Lawn is a very recent phenomenon especially for Xi'an, a city with strong cultural identity. Therefore, it is worthwhile to study the lawns in Xi'an especially in the

heritage parks in order to redesign them to fit into the local culture. In order to better understand lawn introduction to China and get inspiration from the European and Chinese examples of alternative lawns, an additional literature review was done related to (1) the definition of lawns in Europe and China; (2) the origin of lawns; (3) lawn use in classic Chinese gardens; (4) several garden styles using lawns as a crucial element; (5) new looks and ideas for lawns and their alternatives in Europe and China.

3.4 Case study

A case study is broadly defined as a study of a specific event, situation or complex phenomenon investigated in a real world context (Yin, 2003). A large number of thoroughly executed case studies are vital for a scientific discipline in order to systematically produce exemplars, which is the key for an effective discipline (Flyvbjerg, 2006). The case study produces a type of context-dependent knowledge that research on learning shows to be necessary to allow people to develop from rule-based beginners to virtuoso experts. In opposition to the breadth of large samples, the case study analyses a phenomenon in depth (Flyvbjerg, 2006). The case study is more an approach than one specific method, which means that it usually employs a combination of different methods. It is an approach that enables an in-depth investigation by applying multiple analyses of a situation or multiple perspective analysis. There are several types of research questions in landscape architecture for which a case study approach is particularly well-suited. One of them is the question that seeks in-depth understanding about particular types of situations (Van den Brink et al., 2016b). For my study, the research question focused on understanding the lawn phenomenon in Chinese cities.

China's distinct culture differs from Western countries and its serious environmental problems described in Section 1.1 make China an extreme case for lawn use as a globalised landscape, considering both cultural and ecological perspectives. A case study city was necessary for in-depth analysis of lawn in China. However, how to select the case was another question to be considered; it required understanding the social and ecological context of China.

Firstly, the cities in China have similar development patterns, driven by the economic reform in 1978 and its associated policies. They share similar rapid urbanisation, westernisation and globalisation processes. Those processes are more obvious in megacities because of the larger investment and focus from the central government. In addition to the economic reform, in the year 2000 the Western development policy launched by the central government allotted more funding and investments in cities in the Western part of China. During the last 20 years, the western cities have seen rapid urbanisation and urban

build-ups. Today cities in China share similar urban planning, landscape architecture and horticultural management practices in terms of western style planting patterns due to the top-down political structure and market economy, with some centralised planning economy features. The unified establishment and management practices of lawns were applied in all the Chinese cities (GB/T 19535.1-2004; GB/T 19535.2-2004). Based on these criteria, a megacity under rapid urbanisation, Westernisation and globalisation process can be selected as one of the cases.

Secondly, from a biodiversity perspective, it is better that the city is close to a biodiversity hotspot, which could be in contrast to the invasion of exotic species and reveal the overwhelming influence of exotic species. Meaning that if the city with rich natural biodiversity resources becomes homogenous with lawn biodiversity, I could draw the conclusion that the lawn may have contributed the homogeneity of species in urban areas in Chinese cities with less biodiversity resources in the surrounding areas.

Thirdly, another criterion for case study selection is that the city has abundant culture and tradition and specific contextual characteristics that influence its own cultural identity. The lawn is regarded as a symbol of Western culture. When the lawn is incorporated with typical Chinese culture, as a representative Eastern culture, the potential conflicts and the influence they could have on landscape styles in a typical Chinese city with a strong cultural identity are questions that need to be considered.

Fourthly, it is urgent to find drought tolerant alternatives to lawns in Chinese cities in arid and semi-arid regions where the water resource is a major problem. The lawn is criticised for its negative effects on the urban environment. The frequent mowing and management regime as well as drought intolerant grass species require a lot of water for irrigation. It could cause serious problems for cities that lack water resources.

In summary, Xi'an city meets all the four criteria of case selection for lawn phenomenon in Chinese cities. Xi'an is one of the most important megacities and regional centres in China (Huang et al., 2016). Driven by the national Western development program launched in 2000, the economy and urbanisation of Xi'an are growing rapidly (Jaros, 2016). According to Xi'an Statistics Yearbook (2017), the population increased from 5.53 million in 1985 to 8.25 million in 2016. The urban population exceeded the rural population in 2012 and constituted 67% of the total population of Xi'an in 2016 (Figure 5). The built-up area expanded from 133 km^2 in 1985 to 565.75 km^2 in 2016.

Xi'an is located in the middle of the Wei river valley (107º0'-109º49'E; 33º39'-34º45'N) in central China (Figure 6). Xi'an city is in proximity to the Qinling Mountains, which is the watershed between Southern and Northern China as well as an internationally treasured biodiversity hotspot (Zhang et al., 2017). The geophysical conditions within the city represent a temperate semi-arid climate influenced by the East Asian monsoon. Water scarcity is one of the biggest problems in Xi'an. The per capita available water resource in the Weihe River Basin, where Xi'an is located, is less than 350 m^3 per year; far below the line of absolute water scarcity of 500 m^3 per capita per year. The surface water pollution caused by the rapid urbanisation is also a serious issue in the city (He et al., 2008).
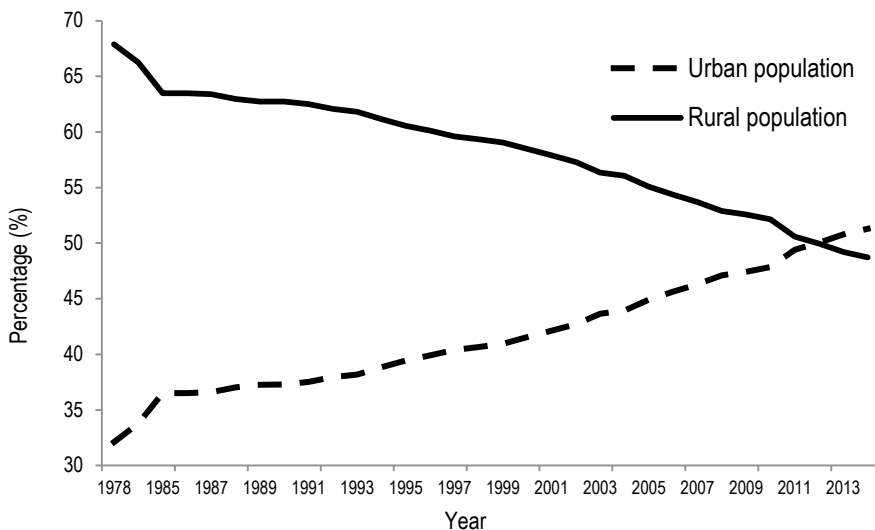
Figure 5. Temporal dynamics of the urbanization levels (% urban population) for Xi'an (XSB, 2015).

Moreover, Xi'an is one of China's most important ancient capitals and has rich archaeological, architectural, and cultural heritage. Many heritage parks were built for preserving the historical relics, as well as providing recreational areas for local residents and tourists. A lot of lawns were used because the shallow roots of turfgrasses protect the relics underneath the ground. According to my observations of 28 public parks in Xi'an city, only two of them did not have lawns as groundcovers. Considering the serious environmental problems caused by the rapid urbanisation, it is urgent to establish resource saving and environ-mentally friendly green spaces in Xi'an (He, et al., 2008).

Figure 6. Maps of China and Xi'an city

The research was conducted in the six most densely populated districts in Xi'an city because they are the most urbanised and developed area of Xi'an city. In order to conduct an in-depth analysis of the case of Xi'an as a representative megacity, multiple perspective analysis was used (Van den Brink et al., 2016a).

3.5 Social perspective

Public lawns are important communication points between local residents and their vision of urban nature. How stakeholders and park visitors perceive lawns influences how the lawns are designed and managed. Another purpose of the social study was to test the possibility of changing current lawn design and management practices. The methods of social sciences were applied in the investigations of social aspect of lawns (e.g. questionnaires, interviews and observations).

3.5.1 Semi-structured interviews

Compared with the structured interview, a semi-structured interview is open, allowing new ideas to be brought up during the interview as a result of what the interviewee says. Nevertheless, semi-structured interviews have a clear focus, following a guide rather than a very general notion of a topic (Bryman, 2016). Therefore, semi-structured interviews were conducted with 18 stakeholders (two local politicians (LP1, LP2), 11 park managers (PM1-PM11), one city gardener (CG), two urban planners (UP1, UP2) and two landscape architects (LA1, LA2) in order to gather information on their perception of lawns. At least one stakeholder within each type of profession were selected. Others were selected according to their availability. Only one or two city gardeners, urban planners, landscape architects and local politicians were interviewed because it was enough to know the general policy and condition of lawn in Xi'an city. Different stakeholders shared similar ideas about lawn design and management in Xi'an by following the same policies in the city. Eleven park managers are interviewed because of their different ideas on managing different parks and lawns. The interviewees worked for the local government in roles related to public park management and green space planning and management. The semi-structured interview schedule consisting of 15 open-ended questions plus prompts was used to guide the interview. The background of the interviewee (educational background, their role in the municipality) was obtained in the interview. I also asked questions about plans and resources regarding lawns, choices of groundcover species, understanding of lawns and their role in modern green areas, about the opportunities for sustainable lawn alternatives and the presence of wildlife as well as how they would like to design the grass area.

3.5.2 Structured observations

In order to accurately report the lawn activities of different groups of park visitors, structured observations were performed by following an observation schedule (Bryman, 2016). Observational studies were performed during a time period of 20 minutes in 22 pubic parks. Different time periods were tested and 20 minutes intervals were most suitable; during a shorter time period in some cases no one was observed to use the lawn and a longer time period would take too much time considering the large number of lawns observed. The observation includes recording the frequency that selected lawns were being utilised and identifying and analysing activities within lawns. In total 52 lawns from 22 public parks in the six most urbanised districts were studied. I visited 28 larger public parks in the studied districts and 22 public parks were selected for the availability of utility lawns (lawns that are open for public use). In each observed park there were only two to three utility lawns (the lawn used for different activities instead of just for looking at) and I tried to cover all of them. Other information such as the age group of lawn users (young, the middle-aged and elderly), gender, date, time and weather were estimated and recorded. Different categories of activities were used for observation. They were (1) walking; (2) exercise/sports, sit/rest; (3) social activities with neighbours/ friends/family (feast, eating, grilling, etc.); (4) get to other surfaces (like passage); (5) take photos; (6) look at (aesthetic value); (7) play (kids).

3.5.3 Face-to-face questionnaires

Six public parks in Xi'an city (one in each district) were selected as study sites for collecting data using questionnaires (Figure 7). These six municipal parks were chosen as they represent typical municipal parks of the city because they have diverse recreational facilities; they are free of charge and offer easy access. They are also used intensively by all segments of the urban population. These six parks were built at different times (from 1927 to 2013) and represent different landscape design styles, though all six parks are covered by large areas of lawns.
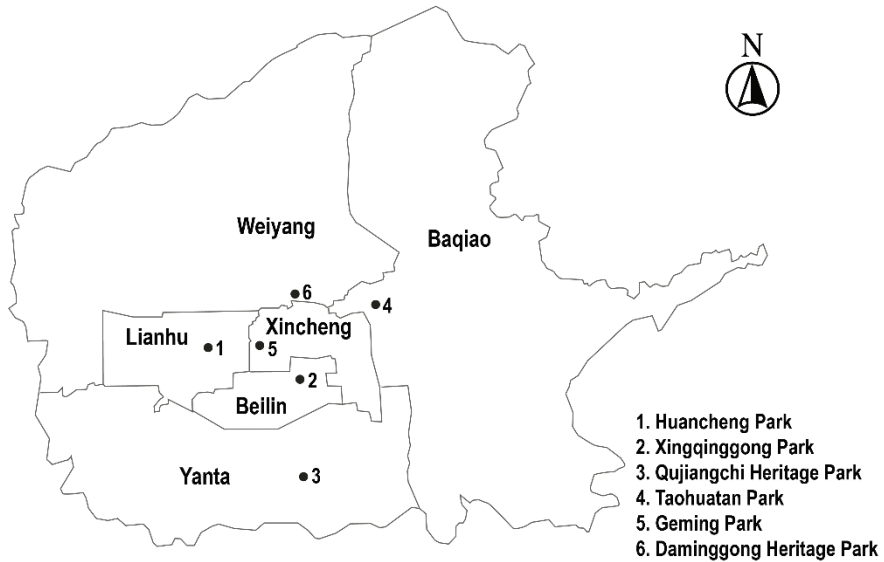
Figure 7. Map of the six districts of Xi'an city and the parks where the questionnaire survey was conducted

Figure 8. Types of herbaceous vegetation in questionnaires: (A) Conventional lawns; (B) The lilyturf (*Ophiopogon japonicus*) groundcover (traditional shade tolerant groundcover); (C) Perennial meadows; (D) The wood sorrel (*Oxalis corymbosa*) groundcover (flowering groundcovers).

Questionnaire is the most commonly used method to get a perception of park visitors in urban green spaces (Kabisch et al., 2015). Face to face questionnaire surveys were done to get park visitors' perceptions about the lawn value, how they wanted the lawns to be used and their preferences about lawns. The stratified random sampling method was used to select samples in order to exhibit a proportional representation of the different parks to which park visitors were attached. Visitors with different age groups and gender were selected. Ten individuals in each of the three age groups (15-34, 35-54, 55 and above) were interviewed in each of the parks. Among the 10 individuals, half were female and half were male. Otherwise the park visitors were randomly selected when they were sitting on the lawns, doing leisure activities, or passing by the lawn to ensure each individual had an equal probability of inclusion in the sample.

Using photographs to inventory public opinion on landscape preference research (Kaplan & Kaplan, 1989) is one of several ways to visualise the landscape for obtaining public feedback. Photographs of four types of herbaceous vegetation (conventional lawns, perennial meadows, wood sorrel (*Oxalis corymbosa*) groundcover, lilyturf (*Ophiopogon japonicus*) groundcover) were shown, and interviewees were asked about their preferences (Figure 8). A perennial meadow is using perennial native and exotic grasses and forbs to create meadow-like communities. They were widely promoted by the Sheffield Landscape Architecture School in the UK and introduced to China in recent years as a replacement for lawns and for its aesthetic value (Hitchmough et al., 2013; Hitchmough & De la Fleur, 2006). The lilyturf groundcover is a monoculture of native herbaceous species and traditionally used in classical Chinese gardens. It is widely spread in China except for Sinkiang, Inner Mongolia, and the north-eastern provinces (Editorial Board of Flora Reipublicae Popularis Sinicae, 1999). It is currently also used in public parks because of its shade tolerance merits and ornamental value. The wood sorrel groundcover is a monoculture of exotic herbaceous species originating in South America. Nowadays it is widely used in China as ornamental plants because of its long flowering period (from March to December) (Editorial Board of Flora Reipublicae Popularis Sinicae, 1999). The aim here is not to recommend any types of the planting regimes or herbaceous vegetation. Using visitors' preferences about different herbaceous vegetation and corresponding explanations of the reasons, the characteristics of favored herbaceous vegetation could be understood, which can later be addressed in the design and management of lawn alternatives. The questionnaire contained both open questions and closed questions. The socio-demographic data such as age, level of education,

gender, household type and occupation status were also collected. Twelve questions were included in the questionnaires (Table 2).

Table 2. Questions in the questionnaires for park visitors in both parks

Number	Questions
1	Are you related to this place?
2	How long have you been using this park?
3	How do you perceive the value of having access to a lawn / grass areas in the public park?
4	How do you see the maintenance of grass areas in this park in general?
5	What do you think about lawns in general? Are you familiar with lawns?
6	What type of lawns do you like best?
7	Which element is the most important for you in the green area of this public park? If you could decide, how would you like to design grass areas in this park? (If grass areas)
8	How would you rate the following statements regarding the grass area in this park (1-disagree to 5-agree)?
9	Do you think that lawns generally create a good environment for many animals to live in, such as insects, birds, mammals?
10	If you have access to the lawns, how would you like to use lawns for? (1-disgree to 5-agree): Exercise / sports; sit/rest; Social activities with neighbours / friends /family; To get to other surfaces (like passage); To experience nature; To look at (Aesthetic value)
11	Which season do you prefer to visit the lawns foremost?
12	Is there anything you would like to add concerning lawns and green areas?

A total number of 202 questionnaires were collected. There were 30 respondents that completed the questionnaire survey at each study site. Special groups of people (dancers, singers and visitors with kids) were interviewed to learn about their demands on lawns because these groups use the park regularly. Twenty-two questionnaires from respondents of special groups were collected. Most of them were leaders of different dancing groups and singing groups. The visitors with children were randomly selected and responses were dependent on their availability. A majority of people with children refused to do the questionnaires because they were busy taking care of their children and worried about their children's safety.

Public parks are one of the most popular places for public plaza dancing. Therefore, dancers are one of the most important user groups in Chinese public

parks (Seetoo & Zou, 2016). Public plaza dancing has been a phenomenon in contemporary Chinese mass culture. In the early mornings and evenings, groups of mostly middle-aged and elderly people (mostly women) dance together in the outdoor space (this area is flat and accessible). Singers are also commonly seen performing in public parks in Xi'an. The visitors with children were selected because they can express their requirements for green spaces from a children's perspective. It is common in China that young couples ask their parents to take care of children because of their busy work schedule or simply as a tradition (Wang, 2017). Public parks are an ideal place for grandparents and their grandchildren.

3.5.4 Data analysis

Quantitative data

The quantitative data and graphs for lawn maintenance from interviews with park lawn maintenance workers and observations, were analysed by using Microsoft excel 2010. One-way analysis of variances (ANOVA) was used to determine significant differences among preferences on different types of activities by using R 3.2.2 (R Core Team, 2013). Similar analysis was conducted to determine the park visitors' preferences of the lawn and its alternatives, park visitors' opinions on the values of lawns.

Qualitative data

Thematic analysis was used to analyse the qualitative data based on the interviews with stakeholders and open-ended questions in the questionnaires with park visitors about their perception on lawns. This analysis was assisted by using the software package Nvivo 11. Specifically, the procedure was done in the following sequence: (1) initial codes were generated based on the predefined research questions and familiarity of the interview data; (2) codes were adjusted and sorted into different levels of themes to show the relationships of different codes; (3) thematic maps were drawn according to the research questions, after revising and renaming the themes; (4) the report was produced based on thematic maps. Adjustments were made to the thematic maps when producing the report (Braun & Clarke, 2006).

3.6 Ecological perspective

3.6.1 Research sites

Table 3. Land area and density of permanent population based on statistics of districts (2013) (XSB, 2015).

Districts	Land area (km², until end of 2012)	Population (10000 persons)	Density of population (person/km²)
Xin Cheng	30.13	59.64	19796
Beilin	23.37	62.23	26623
Lianhu	38.32	70.43	18378
Baqiao	324.50	60.50	1864
Weiyang	264.41	81.84	3095
Yanta	151.44	119.29	7877

This study was conducted in the six most populated districts of Xi'an (Table 3). In total, 28 public parks in the six districts were studied (Figure 9). There were 51 public parks in the six most densely populated districts in Xi'an city in 2016. The 28 parks scattered over the city were chosen because they were larger in size compared with other parks and thereby had a higher chance to have both lawns and other types of herbaceous vegetation. Edge effects on sample plots in larger parks are lower compared with that in smaller parks. The public parks included in the study were state-owned and built for public recreation. They usually contain larger open lawns than the parks built for residents in gated communities (Yao & Wei, 2012).
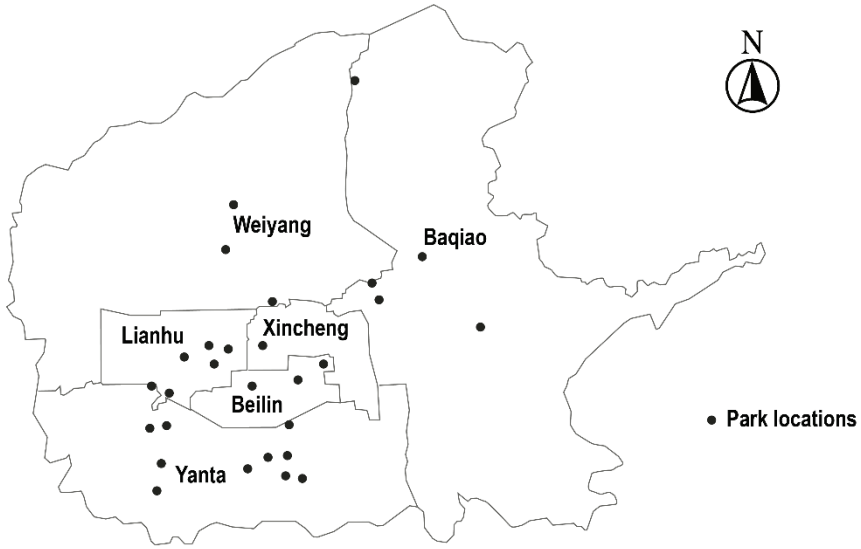
Figure 9. Map of the six districts in Xi'an City included in this study and location of the parks selected for inventory (adjusted from Google maps, 2016).

Figure 10. Herbaceous vegetation types in parks in Xi'an selected for inventory: (A) Lawns; (B) wood sorrel (*Oxalis corymbosa*) ground cover; (C) lilyturf (*Ophiopogon japonicus*) ground cover; (D) perennial meadows.

3.6.2 Sample plots

Stratified random sampling was used to take samples. In China, private lawns are not popular because of the limited land area and high price of villa gardens. Most of the large area lawns are in public parks. Therefore, all of the samples are selected from public parks. In this study, lawns (grass-dominated, regularly maintained plant communities created from grass species not native to China) with ground cover of wood sorrel (*Oxalis corymbosa*, an exotic species) and lilyturf (*Ophiopogon japonicus*, a native species) were compared (Figure 10). The three types of herbaceous vegetation were selected because they are the most commonly used herbaceous vegetation (second after lawns) in the public parks of Xi'an.

A total of 107 sample plots in 28 parks were selected for inventory. They included: 72 lawns, 12 perennial meadows, 15 lilyturf (*O. japonicus*) ground covers, and eight wood sorrel (*O. corymbosa*) groundcovers. Based on the vegetation present, one to seven lawns, ground covers, and perennial meadows were chosen per park. If more than one lawn was selected within the same park, the distance between these was at least 500m. Apart from this criterion, the lawns were randomly chosen within parks. The field survey was conducted from early May to early July in 2016.

3.6.3 Biodiversity inventories

Inventories were conducted in selected sample plots in each studied public park from late April to early July of 2016. The vascular plants and pollinators (bees, butterflies and hoverflies) were studied. The richness, abundance and Simpson diversity index of plants and pollinators are indicators of plant species diversity. Proportion of native species shows the plant species composition of lawns. The pollinator diversity could indicate the abundance and richness of flowering plants in the lawn, which could have aesthetic value. Moreover, the pollinators, especially wild pollinators, are crucial for plant reproduction, human food security and health, and ecosystem functions. It is important to know how much urban green spaces attract pollinators. The plants are the main components of lawns, which are directly influenced by environmental factors and management practices.

Vascular plants

Vascular plants were recorded in four quadrats (50cm×50cm) in each lawn and perennial meadow. Two quadrats were designated in the centre and the other two near the edges of the site. Each quadrat was divided into 25 sub-

quadrats (10cm×10cm) and the presence of each species of vascular plant in the sub-quadrats was recorded to estimate its abundance in the sample plot (Marrugan, 2004). The Simpson Diversity Index was used to compare species diversity of both plants and pollinators under different landscape variables and local variables. It was calculated as: $1 - \sum p_i^2$, where p_i=the proportion of individuals in the ith species. The proportion of native plant species (ratio between native and exotic plants) was also calculated, using the Flora of Qinling Mountains (Cui et al., 1964) to determine whether a plant species was native to the Xi'an region.

Pollinators

Pollinators (butterflies, bees, and hoverflies) were inventoried between 9:00 and 16:00 in fair weather (temperature 20-30℃, sunny to scattered clouds). Point observations of pollinators were made in two quadrats (2m×2m) at each study site, one in the centre and one at the edge of the lawn, ground cover and perennial meadow. Flower species were included in each quadrat. The number of flowers and flowering species and the species of pollinators entering the quadrat were noted. The flowering plants visited during a 15-minute period were noted as well. Pollinator specimens were collected after a 15-minute period and identified by experts in the laboratory if the pollinator could not be identified immediately (Prof. Huanli Xu, Department of Entomology, China Agricultural University). The reference books used to identify pollinators were the Illustrated Handbook of Butterflies in China (Zhou, 1999), Fauna Sinica: Insecta Class (Sinica, 1997), and Chinese Insects Illustrated (Zhang & Li, 2011).

3.6.4 Management and environmental factors

In order to understand the relationship between the biodiversity indicators and their influential factors, the management and environmental factors of lawns and other groundcovers were recorded. To describe the urban environment around each plot, the proportion of green spaces and imperious surfaces within a 300m, 600m, and 1000m buffer radius of each lawn and other herbaceous vegetation (sample plot) was calculated. Park size and the size of each sample plot were calculated by using ArcMap. The canopy density of each sample plot was obtained from satellite maps as well as on-site observations. Maintenance practices of each lawn and other herbaceous vegetation were obtained by interviewing park managers. The maintenance practices include irrigation frequency, use frequency of pesticides and fertilisers, mowing frequency. Public access (yes or no) was recorded on site.

3.6.5 Statistical analysis

Pearson correlation was used for testing the relationships between different environmental and management factors (variables). When variables were highly correlated with each other, thus describing the same gradient, only one of them was selected for the follow-up analysis. As the proportion of green and imperious areas at the three different radii were highly correlated with each other ($r > 0.6$), only the proportion of green space within a radius of 300m was selected for further analysis.

Step-wise regression was used to identify the factors explaining most of the variations in both plant species and pollinator diversity (Simpson index of diversity for plant species, proportion of native plant species, flower richness, and Simpson index of diversity for pollinator species). Regression analysis for plant species diversity was applied on the lawn. The analysis on pollinator species diversity was applied to the four types of vegetation. All the regression and correlation analysis were performed using JMP pro 13.0.

Multivariate methods were used to analyse the variation in plant community composition in lawns and pollinator community composition in all types of ground cover explained by environmental factors. Principal component analysis (PCA) and redundancy analysis (RDA) (gradient <3.0) were used to evaluate the influence of environmental factors on the plant community composition of lawns. Detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) (gradient >4.0) were used to evaluate the effects of environmental factors on the pollinator community composition, for all types of lawn and ground covers. CCA was also used to evaluate the relationship between flower abundance of plant families and pollinator community composition in different vegetation types. The most important environmental variables and plant variables were selected using forward selection. The 999 Monte Carlo permutations were used to estimate significant levels. The false discovery rate approach was used as a way of avoiding the selection of too many non-significant predictors (Šmilauer & Lepš, 2014). Plant species that appeared in less than 17 plots were excluded from RDA to remove the influence of rare species. Pollinator species that appeared in less than 13 plots were excluded from CCA. All PCA, RDA, CCA, and DCA were performed using CANOCO 5.0 (Šmilauer & Lepš, 2014).

4 Summary of papers

In this chapter, a brief summary of Papers I-III are presented. Each paper was handled in a separate section. The key findings from each paper were summarised. In each section the central questions which the paper addresses were outlined, followed by a brief description of the empirical work from the case study. Each section was concluded by presenting the findings of the research as they relate to each article and how these findings have contributed to answering the research questions.

The research started by reviewing the historical development and practices of lawns in China in Paper I. It was concluded that the Chinese people's paradigm on lawns was influenced by the trend of westernisation and globalisation after the 1840s. Shifting the existing paradigm to environmentally friendly lawn aesthetics and bridging the knowledge gap between researchers and practitioners are challenges for achieving sustainable lawn alternatives in China. At present China employs mostly Western examples of lawn alternatives, which also do not fit into the local environment. Therefore, before proposing and implementing practical solutions to turf lawns in China, it is necessary to thoroughly investigate the phenomenon of lawns in China, through understanding people's perceptions of lawns and how it fits into the local environment in specific case study cities.

These challenges and public perception on lawns and their alternatives in a case study city in China were then studied and analysed in Paper II. This study not only enabled us to explore the reasons for the current lawn design and management practices, but also enabled us to bridge the knowledge gap between researchers and practitioners by communicating with local stakeholders, inc-luding landscape architects, urban planners, local politicians, city gardeners and park managers. The public preferences on lawns and their alternatives were identified, which was significant for sustainable lawn design and management suggestions. In Paper III, a biodiversity study of lawns was conducted in Xi'an city, to understand how the lawn use affects the urban biodiversity and what local biodiversity resources can be utilised for future

sustainable lawn alternatives. Another aim of the study is to explore influential factors for biodiversity in lawns and other alternative herbaceous vegetation, providing information for biodiversity-favouring lawn planning and management practices.

4.1 Paper I: Historical Development and Practices of Lawns in China

In the paper, the origin, historical development and practices of lawns in China were traced in order to explore the driving forces of lawn development and find inspiration for sustainable lawn alternatives from classical Chinese gardening and European examples. The empirical wok involving a literature review and site observations was outlined in Section 3.3. This paper creates a better understanding of the lawn phenomenon in China and is a step forward in shifting people's paradigm of lawns in late-adopter countries. The main findings and contributions to each research question were presented in Table 4.

Table 4. Contribution of Paper I to the thesis research questions

Aims	Secondary research questions	Findings and contributions
Related to aim 1	What are the drivers behind the historical development and current practices of lawn design and management in China?	In classical Chinese gardens (CCGs) there were never monocultures and large-scale grassy surfaces for the following reasons: the concept of a flat, open, large lawn area in formal and landscaped garden styles does not fit into the principle and canon of CCG design (enclosed landscape where a winding path led to a secluded quiet place); grasses have no symbolic meaning; the natural beauty of plants in CCG is appreciated, which owes to the philosophy of respect for nature in Daoism.
Related to aim 1	What are the drivers behind the historical development and current practices of lawn design and management in China?	Steppe vegetation and pasture-like landscapes were only appreciated by certain emperors because of their personal interests and relationships with natural pastures from their unique experiences and nostalgia (nomadic tribes).
		Modern lawns in China, together with the technology for establishment and management, were directly adopted from European countries through the colonial culture and in the more recent trend for globalisation.

Aims	Secondary research questions	Findings and contributions
Related to aim 2	Which implications for future sustainable lawn alternatives in Xi'an and China can be drawn and developed from this study?	Classic Chinese Gardens: ground cover species were used according to their ecological characteristics and their suitability for the site conditions, which ensured a diversity of ground cover layers; every species has a symbolic meaning and function according to philosophical concepts, which makes the visits more interesting and culturally acceptable; native species are used due to limitations of communication and transportation.
		Existing alternative practices in Europe and China: ecological management practices of lawns in Sweden; grass-free lawns in the UK; urban meadows in Sweden and the UK; wild herbaceous plants in Tianjin, Beijing and projects by Kongjian Yu; some projects in Chinese cities adopt the ideas of European countries without adjusting to the local context. Thorough investigation of the lawn phenomenon in China by understanding people's perceptions of the current lawn design and management and how it fits into the local environment in specific case study cities is required in order to propose practical solutions to lawns.
Related to aim 2	What are the challenges of changing current lawn design and management in Xi'an and China?	A lack of communication between researchers and practitioners and the unawareness of existing proposals or a lack of concrete and practical solutions adjusted to local physical conditions and culture limit the application of alternative solutions to lawns; People's preferences from idealised lawn aesthetics to ecological aesthetics need to be changed so that they appreciate naturalistic lawn alternatives; selection of appropriate native plant species for establishment of alternative lawns, due to the millennia-long history of the transformation of landscapes in China and the consequent extinction of certain native plant species and invasion of exotic species.
Related to aim 2	What opportunities are there for implementing sustainable alternatives to lawns in the future in Xi'an and China?	Chinese environmental policy of "Ecological Civilisation" supports sustainable development of Chinese society and sustainable projects; the inappropriate use of lawns in China requires sustainable lawn alternatives that fit into the local context.

4.2 Paper II: Public perceptions regarding lawns and their alternatives in China—a case study of Xi'an

This study aims to explore how stakeholders and park visitors relate to lawns (perceive, use and manage) and how this affects their decisions in designing, managing and interacting with lawns and their alternatives in a case study in Xi'an. The empirical data about the perception and preferences of park visitors and stakeholders was collected through semi-structured interviews, face-to-face questionnaires and observational studies (Section 3.5). In Paper II, the megacity of Xi'an was analysed with regards to current lawn use and maintenance. Challenges and opportunities for implementing sustainable alternatives in Xi'an were explored. The main findings and contributions to each research question are presented in Table 5.

Table 5. Contribution of Paper II to the thesis research questions

Aims	Secondary research questions	Findings and contributions
Related to Aim 1	What ecosystem services are provided by the lawn and what factors influence the provision of ecosystem services in Xi'an and China?	Provisioning services: refuge from disasters (openness of green spaces); safe place for children and adults (openness of green spaces). Cultural services: heritage protection (shallow rooted herbaceous plants); aesthetic value (vision of nature and appreciation; landscape preferences of different types of herbaceous vegetation); cultural identity (traditional use of groundcovers, planting regimes, symbolism of plants); educational value (presence of diverse flowers); recreation (the accessibility of lawns); nature experiences (understanding of nature); social relations (social activities, accessibility of lawns). Regulating services: climate regulation (availability of green spaces, shade); soil fixation (groundcovers); air quality regulation (availability of green spaces, carbon emission from mowers); water purification and treatment (water resources for irrigation, water contamination from chemic use)
Related to Aim 2	What are the challenges of changing current lawn design and management in Xi'an and China?	Unawareness of stakeholders and park visitors about the negative environmental impacts from lawn maintenance; gap between the researchers and practitioners and misunderstanding or superficial understanding of 'green spaces' among decision makers; paradigm shift from idealised lawn aesthetics to ecological aesthetics.

Aims	Secondary research questions	Findings and contributions
Related to Aim 2	What opportunities are there for implementing sustainable lawn alternatives in the future in Xi'an and China?	Factors that facilitate the use of sustainable alternatives to lawns: environmental factors, such as climate, limited land resources, locations; economic factors, such as cost reduction in maintenance; social-cultural factors, such as shade intolerance of grass species, biodiversity and environmentally-related attitudes of stakeholders, park visitors' preferences for coloured flowers, unsuitability of existing lawn alternatives

4.3 Paper III: Relationships between multi-scale factors, plant and pollinator diversity, and composition of park lawns and other herbaceous vegetation in a fast growing megacity of China

The aim of Paper III is to illustrate the current biodiversity patterns of lawns and three other common herbaceous vegetation types used in public parks in Chinese cities and obtain knowledge and develop recommendations related to sustainable design and management of lawn alternatives. Therefore, this study compared lawns with three other herbaceous vegetation ground covers in terms of plant and pollinator diversity and composition, by relating them to multi-scale factors using Xi'an as a case study. Plant and pollinator species richness and abundance, proportion of native plants, Simpson index of diversity of plant and pollinator species were used as biodiversity indicators and were inventoried and calculated in lawns and three other common herbaceous vegetation types, (i.e., perennial meadows, *Ophiopogon japonicus* ground covers and *Oxalis corymbosa* ground covers). The detailed methods were outlined in Section 3.6. Factors significantly related to plant and pollinator diversity and composition of different herbaceous vegetation, were identified in order to propose suggestions in favour of lawn biodiversity and other herbaceous vegetation. The main findings and contributions to each research question were presented in Table 6.

Table 6. Contribution of Paper III to the thesis research questions

Aims	Secondary research questions	Findings and contributions
Related to Aim 2	What ecosystem services are provided by the lawn and what factors influence the provision of ecosystem services in Xi'an and China?	Pollination: 27 pollinators were observed to visit the studied herbaceous vegetation, of which 12 are solitary bees; the most abundant pollinator is the cultivated honeybee, which may threaten the survival of wild native bee species; most of the species among the lepidopterans and syrphids are widespread and common, which indicates the impoverished pollinator community; flowering plant species richness was a crucial factor for the diversity of pollinator species visiting flowers within the four vegetation types studied in Xi'an; *Ophiopogon japonicus* is attractive to native bees (*Lasioglossum subopacum*, *Lipotriches burmica*) from the family Halictidae; The open and shallow flowers of *Taraxacum mongolicum* and *Ixeridium chinense* (family Asteraceae) are favored by Syrphidae.
Related to Aim 1	What is the plant species diversity and composition of lawns and the influential factors in Xi'an?	Although native plant species were rich in lawns (69 of 91 species), they were less dominant. An exotic species covered on average 32% of a quadrat while native species on average covered 10%; In perennial meadows, native plant species were less dominant (an average coverage of 9% per quadrat) than exotic plant species (23%); the *Ophiopogon japonicus* (native) and *Oxalis corymbosa* (exotic) groundcovers were considered monocultures with coverage exceeding 90%; environmental factors explained more of the variation in plant species diversity than in plant species abundance; proportion of green space, lawn age, lawn size had a positive effect on plant species diversity and flowering plant richness in lawns, while chemical fertiliser use had a negative effect on plant diversity and proportion of native plant species in lawns and perennial meadows; mowing frequency, had negative effects on the proportion of native plant species; when planning, designing and managing lawns and its alternatives, the influential factors need to be adjusted in favour of plant diversity in the alternatives.
Related to Aim 2	Which implications for future sustainable lawn alternatives in Xi'an and China can be drawn and developed from this study?	To increase the biodiversity of herbaceous vegetation, the proportion of green spaces should be increased and older and larger lawns could be maintained; management in a less intensive manner (less mowing, less chemical fertilisers) increase the richness of flowering plant species and the related pollinator diversity; some native plant species could be planted and maintained for attracting native pollinators

5 Discussion

In this chapter the main empirical findings and analysis are discussed from a theoretical framework and theoretical arguments are presented in relation to the research questions, other research findings in the field and in general lawns as a current phenomenon in society. In order to realise the transition from lawns to sustainable alternatives in Chinese cities, the historical development, current situation and future possibility of lawns and their alternatives and their social-cultural, economic and environmental drivers were analysed. Relevant theoretical development and future research were addressed too.

5.1 Research question 1: What are the historical context and current situation regarding lawns in China?

5.1.1 What are the drivers behind the historical development and current practices of lawn design and management in China?

This section explains and discusses how and why the lawn, as a common element of urban green spaces, developed in Chinese cities in the past. It was addressed by reviewing literature and visiting historical lawn sites and observing lawn-related practices in Chinese cities (Paper I). The main results were obtained by reviewing the history of classical Chinese gardening. It is evident that there were never monocultures and large-scale grassy surfaces in classical Chinese gardens based on how plants were used in the gardens. Paper I shows that (1) the concept of transplanting pastures or meadows and imposing intensive management on grassy areas are not accepted in classical Chinese gardening because of the ideology respect for nature; (2) a variety of native plant species were used according to their ecological character and aesthetic preferences related to philosophical beliefs; (3) the European concept of a flat, open, large garden area in formal and landscape garden styles is very

different from the enclosed landscapes where a winding path led to a secluded quiet place in classical Chinese Scholar's gardens; 4) the grass was modest for the owners and designers of the gardens and no symbolic meaning was endowed to it.

Paper I concludes that contemporary lawns in China, together with the technological tools for their establishment and management, were directly adopted from Western countries through the colonial culture, and in more recent times, from trends encouraged by globalisation. There were some exceptions of appreciation of steppe vegetation and pasture-like landscape by certain emperors because of their special experiences and nostalgia (*i.e.* those who came from nomadic tribes). The European ideal of the lawn in the twentieth and early twenty-first centuries was a monoculture of low and frequently cut grassed areas. This lawn typology was common in Baroque gardens and Picturesque and Gardenesque landscape styles (Boults & Sullivan, 2010; d'Argenville, 1728; Jellicoe & Jellicoe, 1987; Loudon & Loudon, 1850; Ignatieva, 2011). It also fits well into the utilitarian style of Modernism (Thompson, 2009).

The comparison of lawn development and practices in China and Europe in Paper I revealed that lawns have changed from being an interesting and relatively small-scale decorative element, which from the beginning was quite biodiverse (*e.g.* medieval times in Europe and early colonial lawns in Chinese cities), into a large-scale monoculture that requires intensive management. The change in the appearance of lawns corresponds to the change in the relationship between humans and the environment. Specifically, the relationship has changed from one of essential harmony in agricultural or pre-modern civilisation to one of conquest of modernism over the environment (Bao, 2004). People's ideas of control or conquest over nature are reflected by the intensive management practices they impose on lawns to keep them tidy and in order.

The European examples of lawn alternatives were reviewed in Paper I in order to get some inspiration for sustainable lawn alternatives and learn lessons from their experiences. In Europe there are grass-free lawns (Smith & Fellowes, 2013; 2014), enamelled meads (Woudstra & Hitchmough, 2000), pictorial meadows and naturalistic plantings and "go wild" spontaneous planting (Ignatieva, 2018). Ecological management of lawns where use of pesticides and herbicides are decreased or prohibited, are applied in European countries (Sarlöv-Herlin et al., 2010). These Western examples started to be fashionable in other countries including China in 2000s. However, whether they are applicable in a Chinese context is still uncertain due to different social-cultural and environmental contexts.

The conclusion from the study in Paper I is that it is necessary to thoroughly investigate the specifics of Chinese lawns by understanding people's perceptions of the current lawn typology and how it fits into a particular local environment before proposing and implementing practical solutions to turf lawns in China. The in-depth analysis of Chinese history and the development of lawns provided a deeper understanding of the driving forces behind the fast development of lawns and acceptance by authorities. It also shed light on how to search for sustainable lawn alternatives that can be culturally acceptable for both decision makers and common visitors.

5.1.2 What is the plant species diversity and composition of lawns and the influential factors in Xi'an?

As defined in section 2.1.2, sustainable lawn alternatives are biodiverse and provide multiple ecosystem services. Therefore, knowledge of the relationships between environmental and management factors and species diversity is vital for design and management decisions that favour lawn biodiversity. This question was addressed in Paper III.

The results in Paper III showed that the average number of plant species per quadrat in both lawns and perennial meadows in Xi'an is fewer than that of lawns in Swedish cities (Jörgen Wissman, unpublished data). This could be explained by less intensive maintenance (no weeding, no chemical fertilisers and pesticides) of Swedish lawns, which reflect a more environmental friendly lawn maintenance practices.

In Paper III, the core grass species (*Lolilum perenne* and *Poa pratensis*) found in lawns in Xi'an were in accordance with other geographically distant regions, such as Paris, Christchurch, Sheffield, Southwestern Hungary as well as cities in the United States (Bertoncini et al., 2012; Pal et al., 2013; Stewart et al., 2009; Thompson et al., 2004). This indicated a homogenisation of lawn plant composition worldwide. The lawns in Xi'an were dominated by exotic grass species, which were also found in lawn studies in non-European cities such as Christchurch (Stewart et al., 2009) and Santiago de Chile (Fischer et al., 2016). Some native herbaceous plants such as *Duchesnea indica*, *Medicago lupulina*, and *Oxalis corniculata* were the most abundant native plant species in Xi'an lawns, and could be recommended as potential drought- and trampling-resistant alternatives to non-native grass species.

According to Paper III, lawns and the newly-introduced perennial meadows, which are supposed to be more environmentally friendly compared to lawns, were potential sources of invasive plants due to the dominant species in those two types of herbaceous vegetation. In total 18 invasive plants were recorded in

lawns in Xi'an. Among the dominant species in lawns and perennial meadows, *Lolium perenne*, *Oenothera rosea*, *Coreopsis basalis*, and *Trifolium repens* have been declared invasive (Yan et al., 2014). *Erigeron canadensis* was present in most studied lawns and is considered an invasive plant species in China (Yan *et al.*, 2014) and France (Bertoncini *et al.*, 2012). This implied that green areas in cities may harbour many species but they may also be sources of invasive species when exotic plant species are intentionally used.

As shown in the findings presented in Paper III, plant species diversity was affected by a combination of landscape and local variables. The proportion of green space as an indicator of urbanisation had a positive effect on plant species diversity and flowering plant richness in lawns in this study. Older lawns in Xi'an had a higher diversity of plant species and higher numbers of flowering plant species. This confirmed that, over time, originally sown *Lolium perenne* becomes less competitive and gives way to other species. According to the results presented in Paper III, larger lawns probably harbour a higher proportion of native plant species. This shows that large areas of contiguous lawn with better connectivity enable spontaneous native species to spread and grow in the area.

The negative effects of chemical fertiliser on plant diversity and proportion of native plant species in lawns and perennial meadows were detected in Xi'an in Paper III. Over-application of chemical fertilisers will cause serious soil acidification problems, lower the nutrient-use efficiency of plants as well as water pollution (Miao et al., 2010). Some studies also reported restraining effects of urea fertilisers on seed germination and seedling growth of plants in soil (Bremner, 1995). Use of fertilisers also promotes the growth of exotic species that require nutrient rich soils. The exotic species compete with the native species (most of which originally grow in poor soil) for resources and space (Bretzel et al., 2016).

Furthermore, the results presented in Paper III showed that frequent mowing had negative effects on the proportion of native plant species. Most plants in lawns can hardly be reproductive because of frequent mowing. Therefore, a decrease of seed dispersal and less diversity of plant species are found in lawns.

5.1.3 What ecosystem services are provided by the lawn and what factors influence the provision of ecosystem services in Xi'an and China?

This question was addressed by evaluating the results obtained from the social-cultural and ecological studies in Paper I, II and III. The concept of ecosystem services is used as a framework to summarise, analyse and discuss the results (Table 7).The influential factors for the provision of different ecosystem

services were analysed to offer suggestions as to how to adjust those factors to design and manage sustainable lawn alternatives in Chinese cities (Table 7).

Table 7. Biodiversity of lawns, the assessed and perceived ecosystem services provided by lawns, their influential factors and implication for sustainable alternatives (see notes on +,-, +/- below)

Biodiversity	Indicators	Data sources	Influential factors	Implication for sustainable alternatives
Plant species diversity and composition	Plant species diversity +/-	Plant species inventory from field work	Proportion of green spaces; age of lawn; fertiliser use frequency	Higher proportion of green spaces around lawns; keeping the older lawns; less fertiliser
	Native species (exotic species; invasive plants) -	Plant species inventory from field work	Lawn size; fertiliser use frequency; mowing frequency; use of exotic species	Lawn size increase; less chemical fertiliser use; less mowing; less use of exotic species

Perceived (demanded) ecosystem services		Data sources	Influential factors	Implication for sustainable alternatives
Provisioning services	Refuge for disasters +	Semi-structured interviews with stakeholders	Openness of the space	Keep certain open green spaces in urban areas; use more groundcovers
	Safe place for children and adults +	Questionnaires	Openness and luminosity of urban green spaces	Keep certain open green spaces in urban areas
	Groundcover under shade -	Semi-structured interviews with stakeholders	Shade tolerance of groundcover species	*Ophipogon japonicus*; search for new native groundcovers from local biodiversity pools such as Qinling Mountains
	Water availability and quality-	Semi-structured interviews	Frequent irrigation and use of chemical fertilisers: water resources for irrigation, water contamination from applying chemical fertilisers	Drought-tolerant species with less irrigation; less chemical fertilisers (native species needs less nutrients)
	Air quality regulation-	Semi-structured interviews	Frequent mowing: carbon emission from fossil fuel burning for mowers and N_2O emission from use of chemical fertilisers;	Low growing herbaceous plants which will require less mowing; less chemical fertilisers (native species needs less nutrients)

Perceived (demanded) ecosystem services		Data sources	Influential factors	Implication for sustainable alternatives
Cultural services	Heritage protection +	Semi-structured interviews with stakeholders	Shallow-root herbaceous species	Research on the root system of local herbaceous species and identify potential species
	Aesthetic value: neatness + ; Colourful and diverse flowers (diverse landscape) -	Questionnaires	Proportion of green spaces; age of lawn; neatness (change of the vision and appreciation of nature; landscape preferences of different types (colourful flowers) of herbaceous vegetation; flora and fauna diversity	Other types of the species, try to break up with Western 18th century vision of nature; introducing ecological aesthetics and education
	Educational value-	Semi-structured interviews	Presence of diverse flowers and wild animals	More flowering plants to attract more pollinators: increase floristic diversity
	Recreation (accessibility) -	Questionnaires	The accessibility of lawns; recreational activities	Some open to visitors; experimentation with trampling-tolerant species; less weeding; fenced ones for replanting; some regulated public access
	Nature experiences +	Questionnaires	Understanding of nature; the vision of nature	Depending on the understanding of nature; biodiverse or monoculture; ecological education
	Social relations (accessibility) -	Questionnaires	Social activities (accessibility)	Accessibility; experimentation with potential trampling tolerant species

Perceived (demanded) ecosystem services		Data sources	Influential factors	Implication for sustainable alternatives
Regulating services	Climate regulation (cooling effect, thermal insulation in winter)+/-	Semi-structured interviews with stakeholders; questionnaires	All green spaces; shade for local climate; frequent mowing and fertiliser use emit greenhouse gases.	Availability of green spaces; less mowing and fertilisers on lawns; low growing native herbaceous plants requiring less mowing and fertilisers
	Soil fixation (dust reduction, erosion regulation) +	Semi-structured interviews; Semi-structured interviews with park managers (assumed from intensity of maintenance)	All herbaceous plants	Soil fixation plants
	Habitat for animals (e.g. pollinators) -	Questionnaires	Flowering plant species richness; availability of certain plant species for native bees and hoverflies	Proportion of green spaces; age of lawn; Flowering plant species richness, certain plant species attractive to certain pollinators

Assessed ecosystem services		Data sources	Influential factors	Implication for sustainable alternatives
Cultural services	Heritage protection +	Semi-structured interviews and map analysis (proportion of lawns in heritage parks)	Shallow-root herbaceous species	Research on the root system of local herbaceous species and identify potential species
	Aesthetic value: neatness + ; colourful and diverse flowers (diverse landscape) -	Questionnaires (park visitors' preferences for different herbaceous vegetation)	Proportion of green spaces; age of lawn; neatness (change of the vision and appreciation of nature; landscape preferences for different types (colourful flowers) of herbaceous vegetation; flora and fauna diversity	Other types of species, try to break up with Western 18th century vision of nature; introducing ecological aesthetics and education
	Cultural identity (sense of place) -	Historical reviews (principle of plant allocation in classical Chinese gardens)	Type of groundcovers used; symbolism of each plant in historic landscapes	Traditional groundcovers (*Ophiogon japonicus*); other flower meadows in imperial gardens; natural grasslands in China as a source for inspiration
	Recreation +/-	Observation (public access; park visitors' activities on lawns)	The accessibility of lawns; activities	Some open to visitors; experimentation with trampling-tolerant species; less weeding; fenced ones for replanting; some regulated public access
	Social relations +/-	Observation (visitors' activities on lawns)	Social activities (accessibility)	Accessibility; experimentation with potential trampling-tolerant species
Regulating services	Pollination (flower richness) +-	Pollinator species inventory from field work (pollinator species richness, abundance, Simpson Diversity Index)	Flowering plant species richness; availability of certain plant species for native bees and hoverflies	Proportion of green spaces; age of lawn; flowering plant species richness, certain plant species attractive to certain pollinators

Note: "+" means provision or facilitating the provision; "-" means no provision or undermining the provision; "+/-" means that some provides and some not, which depends on the context.

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Provisioning services

The lawn can function as refuges for disasters where open spaces provide the local residents space to gather for emergency escape routes and disasters (Paper II). The Design criterion for urban disaster refuge space in urban green spaces was launched by the Ministry of Housing and Urban-rural Development of the People's Republic of China in January of 2018 (Sichuan HURD, 2018). The tent establishment and helicopter parking apron area must be reserved in the UGSs, where only groundcovers and lawns are planted instead of trees and shrubs. In this context, this service could be provided by other groundcovers as well. Park visitors recognised the value of lawns as a safe place for children and adults (Paper II). However, most park lawns are not accessible for the public, which diminishes their potential provisioning service.

Cultural services

The aesthetic value (neatness and uniform green colour) of lawns is appreciated by both park visitors and stakeholders (Paper II), which could be influenced by the acceptance of the Western fashion of picturesque park-like landscape. Western influence, as a reason for the prevalence of lawns in Chinese cities, has already been discussed in Paper I. The local government officials back from their international tours were impressed by the Western landscape styles and want to mimic them in public spaces of China (Yu & Padua, 2007). Due to the global dominance of lawns, the preference switched from wild landscapes to tended and neat landscapes (Williams & Cary, 2002; Yang et al., 2018). Therefore, to keep the lawn "clean and tidy", intensive maintenance was applied to lawns in Xi'an as well as many other Chinese cities. Apart from that, the lawn was regarded as a symbol of status and economic success, which is the same idea as 18th century British lawns because one had to be rich enough to afford to hire all the labourers needed to cut it (Steinberg, 2006). Moreover, the turf lawns have a merit of covering ground quickly because of the advance and adequate prefabricated turf establishment technology. This merit seem to promote the lawn use in the parks in order to achieve the goal of building "green" as found in the study in Paper II.

Nevertheless, flowering groundcovers other than lawns were favored for their colourful flowers by park visitors (Paper II). In previous studies, colour was revealed as an important influential factor of aesthetics in appreciation of plant communities (Botzat et al., 2016). For instance, meadows containing colourful flowers were preferred to simple green (Lindemann-Matthies & Bose, 2007). Grass swards with flowering native herbs or occasionally mown grass swards with colourful flowering herbs are preferred by road users in

northern England for revegetation along roadside verges (Akbar et al., 2003). This could explain why park visitors did not like the traditional groundcover *Ophiopogon japonicus* for its dark leaves as shown in the findings of Paper II. Thus, enhancing the species richness of flowering plants in lawns and other herbaceous vegetation could be a strategy to enrich flowering plant species diversity to meet social needs. The findings in Paper III revealed that the proportion of green spaces around the lawns and the age of lawns are positively related to the flowering plant species richness.

In terms of cultural identity, the lawn was regarded as a symbol of Western culture. Instead, herbaceous plant species used in classical Chinese gardens (CCGs) could symbolise the Chinese culture. For example, the lilyturf *Ophiopogon japonicus* was highly valued for the space between stones under terraces in classical Chinese gardens, according to findings presented in Paper I. In classical Chinese gardens, every species was planted for a reason and has its own story to tell, which makes the garden tour more interesting and culturally acceptable. Moreover, native species were used due to the limitations of resources and transportation opportunities. This is respected because maintenance of native species was resource-saving and environmentally friendly; their natural beauty was appreciated, which owes to the ancient Chinese philosophy.

The Heritage protection function of lawns was perceived as important for Xi'an as one of the most important ancient capitals in China (Paper II). This could also explain the large portion of lawns (more than 90%) used in Qujiang Heritage Park and Daming Palace Heritage Park as presented in Paper II. The shallow root systems of herbaceous vegetation are required for protecting the heritage artifacts underneath the plants (Bai & Liu, 2015). As concluded in Paper II, further investigation is needed of the root system of the local herbaceous vegetation when designing the plant communities in heritage parks.

The spontaneous plants, such as dandelions in lawns and the pollinators attracted by them, were appreciated for their educational values for children to obtain knowledge of nature (Paper II). Therefore, diverse flowering plant resources as well as the associated pollinators in lawns are vital for the provision of this service.

The accessibility to lawns was important for park visitors to do recreational activities and building social relations. However, Chinese lawns have significant differences from the lawns in Western cities. Most lawn areas limited public access due to the tremendous number of park visitors and associated damages (Paper II). The value of doing exercises and social activities were least appreciated by the park visitors compared with experiencing nature and aesthetic values (Paper II). However, the park visitors'

understanding of nature could influence their appreciation of the nature experience. For those lawns open to the public, park visitors were found to perform more different activities on lawns than in Western countries. Park visitors in this study liked to sit and rest and do social activities with their friends and family, while people in Sweden, for example, mostly used lawns as passages and for walking and more rarely for social activities due to climatic (cold climate with snow cover) and historic traditions (Ignatieva et al., 2017). Cultural differences influenced people's use of urban green spaces (Özgüner, 2011). Chinese residents in USA preferred passive activities such as walking, people-watching, sitting and chatting over active activities, such as playing basketball and tennis which is popular in the mainstream Anglo American culture (Zhang & Gobster, 1998). Other factors such as age also affected park visitors' activities on lawns. The elderly people were less active in using the lawn than the young, probably due to the different perceptions of green spaces. The older the respondent, the more likely they are to perceive the green spaces as nature-like, rich in species, lush, beautiful, and varied (Ode Sang et al., 2016). The monotonous, species-poor lawn is probably not that attractive for elderly people.

Regulating services

The findings from Paper II showed that some regulating services provided by lawns, such as cooling effects, dust reduction and microclimate regulation, were most recognised by both park visitors and stakeholders, which may be due to their awareness of the environmental problems in China that are directly connected to people's life (Fu et al., 2007). The soil fixation function of grass species (dust reduction, erosion regulation) is necessary, especially for the Northwestern part of China where the loose soil is easily blown away (Zhang et al., 2004). However, herbaceous vegetation could generally function as soil fixation plants.

The detrimental effects from the intensive maintenance on lawns affected the ecosystem services that relate to air quality regulation and water availability and quality. Far more intensive maintenance practices on lawns were found in Xi'an as a fast-growing megacity in China than in Western cities such as Paris (Castex et al., 2018), as described in Paper II. The frequent irrigation of lawns could put pressure to water resources. Local stakeholders found it was a problem to irrigate lawns in Northern cities due to water scarcity issues. The carbon dioxide emissions from frequent mowing and N_2O emission from use of chemical fertilisers also contributed to global warming effects (Gu et al., 2015).

In terms of pollination, twenty-seven pollinator species were observed, of which 12 were solitary bees (Paper III). Because of adaptation to the local climate and the different structure of flowering species, wild bees had a higher pollinating efficiency than managed bees (Xu et al., 2009). The cultivated honeybee (*Apis mellifera*) was the most abundant pollinator species observed but risks threatening the survival of wild native bee species, (e.g., the closely related *A. cerana* and other wild bee species), if resources are limited (Li, 1991). Biodiversity indicators, such as the richness of flowering plant species, were crucial factors for the diversity of pollinator species visiting flowers within the four studied vegetation types in Xi'an.

The types of herbaceous vegetation are found to influence the attraction of native pollinators in Paper III. *Ophiopogon japonicus* groundcover was found to be attractive to native bees (*Lasioglossum subopacum*, *Lipotriches burmica*) from the family Halictidae (Paper III). However, the contribution of the monoculture of *O. japonicus* to pollinators was limited because it has a short flowering time (late June to early July).

Hoverflies were not only important wild pollinators, but also act as biological control agents (Sommaggio, 1999). The findings presented in Paper III showed that the open and shallow flowers of the plant species *Taraxacum mongolicum* and *Ixeridium chinense* (family Asteraceae) in lawns were favoured by hoverflies, which have relatively short mouthparts (Larson et al., 2014). Pollinators are dependent on the availability of food sources during the whole growing season (Xu et al., 2009). From this perspective, common flowering weeds (especially native weeds) in lawns help support pollinators that are essential to urban environments. The factors discussed in section 5.1.2, which influence the diversity of flowering weeds in lawns, will therefore affect pollinator diversity and the provision of pollination services.

5.2   Research question 2: How could the transition from current lawns to sustainable alternatives be achieved in a Chinese context?

In this section, after recognising the historical contexts and current situations regarding lawns in Chinese cities, detailed suggestions on planning, design and management of sustainable lawn alternatives were proposed according to the context (location, use, microclimate, preferences etc.) in order to achieve the trade-off of multiple ecosystem services provided by herbaceous vegetation layers. Although challenges were recognised to applying sustainable lawn alternatives in Chinese cities, the present social-cultural, environmental and economic conditions in China encourage their implementation.

5.2.1 What implications for future sustainable lawn alternatives in Xi'an and China can be drawn and developed from this study?

Based on the analysis of ecosystem services provided by lawns, as well as their influential factors for the provision of ecosystem services, the suggestions of sustainable lawn alternatives were offered through a series of planning, design and management strategies.

Planning

As concluded in Paper III, high proportions of green spaces in the city, large and connected lawns, and older lawns provide habitat for diverse types of plants, flowering plant species as well as a higher proportion of native plants. However, large lawns were not suggested by urban planners because of limited land resources in urban areas (Paper II), which needs to be considered when planning new lawns. Diverse plants, especially native plants and flowers, were not only attractive for native bees and hoverflies (Paper III), but also attractive for park visitors (Paper II). However, balancing the proportions of green and impervious spaces is challenging in a time of rapid urbanisation. The results in Paper II showed that interesting, sustainable alternatives with native herbaceous plants could be introduced in suburban areas, informal parts of the park and fenced and unused lawns and the lawns in heritage parks could be transformed to increase urban biodiversity and aesthetic value as well as educational functions.

Design

In shaded areas, shade-tolerant herbaceous plants such as the lily (*Ophiopogon japonicus*) could be used to cover the ground and also function as a cultural symbol for its traditional use in classical Chinese gardens. However, it is disliked by the park visitors for its dark colour and its contribution to pollination is limited for its short flowering season. Paper III's results revealed that there is a great potential for Xi'an to make use of low-growing spontaneous native plants as a ground cover, considering their high species richness, attractiveness to native pollinators, low maintenance and educational benefits. Some potential plant species were identified, *e.g.*, *Duchesnea indica*, *Oxalis corniculata*, *Medicago lupulina* for future lawn alternatives in Paper II, but further studies are required to test and evaluate their performance. "Grass-free lawns" (Smith & Fellowes, 2014) could be tested in some public parks by selecting low-growing native forbs, which are trample- and drought-tolerant.

In heritage parks, herbaceous vegetation with shallow root systems could be used for protecting the historical relics underneath the soil, though this requires

further studies on the root systems of herbaceous vegetation. Perennial meadows with a mixture of perennial native herbaceous plant species could be a solution for replacing part of the grassy areas in heritage parks. Nevertheless, certain areas of lawns should be maintained, which is a "cues to care" approach indicating the presence of design and human care for perennial meadows (Nassauer, 1995). This approach would probably be more acceptable for the park visitors who appreciate idealised lawn aesthetics. Drought tolerant herbaceous species are needed in order to save water resources in the regions with semi-arid and arid climates. Herbaceous plant communities with colour and diverse flowers were recommended because they are attractive to park visitors as well as diverse pollinators (Paper II and III).

The concepts and means of arranging groundcover species in classical Chinese gardens could be learnt when proposing sustainable solutions to lawns in Chinese cities (Paper I). Diverse ground cover species could be applied according to their ecological characteristics and their suitability for the site conditions; certain herbaceous vegetation could be used because of its symbolic meaning, as in the classic Chinese gardens. Moreover, it can be suggested to use native species for their resource-saving and environmentally friendly maintenance; their natural beauty could be appreciated, which relies on people's preferences about the aesthetic value of green spaces. The philosophical roots of "unity of man and nature" and "respecting nature" in Daoism and Confucianism in Chinese society helps shift people's preferences from idealised lawn aesthetics to ecological aesthetics. Educational programmes might be helpful to remind the public of the philosophical roots of "unity of man and nature". Additionally, they can infuse ecological science into public policies, the public's aesthetic sensibilities and the development of new technologies for the lawn care industry (Paper II).

Management

As concluded in Paper III, some turf surfaces, which were cut more often in the public parks, could be reserved and open for public access for taking wedding pictures or leisure activities for park visitors (Paper II). Adjusting to less intensive lawn management practices is the key to enhancing the biodiversity of plants and pollinators in public parks. Less maintenance efforts (in the case of Xi'an: less mowing, chemical fertiliser use, no weeding) allow the spontaneous plants in the lawn to grow and flower, which not only provides pollination opportunities for pollinators, (e.g. bees, butterflies) but also provides aesthetic value and educational benefits for the park visitors (Paper II and III). This practice could be first applied in the transformation of heritage parks and public parks in the urban areas. Less

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maintenance efforts also help regulate the air quality by reducing carbon dioxide emissions from mowers and reduce water use for irrigation and potential water contamination from chemical uses for fertilising and pest control.

5.2.2 What are the challenges of changing current lawn design and management in Xi'an and China?

The findings in Paper II showed the recognition and appreciation by park visitors and stakeholders of the ecosystem services lawns provide, especially the cultural services (*i.e.* aesthetic value) and regulating services (i.e. air quality regulation, soil fixation, and climate regulation). This could explain the reason for the prevalence of lawn use in Xi'an as well as other Chinese cities. However, it also increases the difficulties in changing current lawn design and management in Chinese cities. The solution most likely lies in educating the public about the negative environmental impacts from lawn maintenance (e.g. the global warming potential, invasiveness of imported grass species, water consumption, the risks of water and soil contamination from chemical use). The negative impacts from using lawns have not been fully recognised by neither stakeholders nor park visitors as presented in Paper II. However, the stakeholders are seemingly aware of the difficulties and the high costs of establishing and managing lawns because of limited water resources and funding in Xi'an, as described in Paper II.

Another challenge is the gap between researchers and practitioners and misunderstandings or a superficial understanding of 'green spaces' among decision makers. According to Paper II, the decision makers' unawareness of existing proposals or a lack of concrete and practical solutions, which are adjusted to the local climate and culture, limit the application of these proposals. Although there is a large potential for the use of native herbaceous plants, breeding and domestication take time and effort before they can be easily applied (Barth & Milbourne, 2013). Moreover, due to a millennia-long history of landscape transformation in China and the consequent extinction of certain native plant species and invasion of exotic species, it is very difficult to select appropriate native plant species. Moreover, by simply bedding out green lawns, city gardeners could quickly and efficiently fulfil the requirement of building 'green' goals (usually emphasising the areas of green spaces) in city green system planning. However, the quality of green spaces (biodiversity, the provision of ecosystem services) is hardly considered by decision makers.

The shift of people's preferences from idealised lawn aesthetics to ecological aesthetics is the biggest challenge to implementing biodiverse lawn

alternatives in public green spaces in Chinese cities. The public has not recognised the adverse effects of the manicured turf lawns brought to the local environment and their daily life according to our analysis in Paper II. In China, some influential projects such as Kongjian Yu's projects (Paper I) may gradually change the publics' perception of lawn aesthetics by letting them experience another type of landscape. But Yu's projects compromised a lot in term of park locations, native plant species used and management intensity due to pressure from local governments. The decision makers thought that the parks designed by Yu were too "wild" and should not be in urban areas. Apart from that, people's understanding of nature also influenced their experiences of nature based on lawns. By highlighting the need for a paradigm shift and suggesting new ways of designing and managing lawns, people's paradigm could gradually shift through seeing, experiencing and interpreting new types of landscapes.

5.2.3 What opportunities are there for implementing more sustainable lawn alternatives in the future in Xi'an and China?

A series of environmental, social and economic factors facilitate and drive the exploration and use of sustainable alternatives to lawns in Xi'an and China. They were summarised based on the findings from Paper II and Paper III.

Environmental factors

Physical factors such as climatic conditions and urban land resources limit lawn use (Paper II). The drought and hot climate in Xi'an do not favour the growth of cold season grasses in Xi'an. The hot summer increases transpiration and causes a high occurrence of pests and fungi in the lawn (Castex et al., 2018), which could be the reason for frequent irrigation and use of pesticides. According to the findings in Paper II, Limited land resources in the urban areas require multifunctional green spaces that would provide multiple ecosystem services. However, the manicured monoculture lawn cannot fulfil these requirements.

   Some potential locations to use biodiverse herbaceous vegetation were identified according to our interview with the local politician (Paper II). It is suggested that biodiverse herbaceous vegetation could be used in suburban or remote regions. Managers in the UK also suggested to use biodiverse perennial meadows at the edge of a town or by a river because of the people's expectations to see "cues to care" in front of their homes (Hoyle et al., 2017). Moreover, the heritage park is a potential location for transforming current lawn design and

management practices into sustainable alternatives (Paper II). However, a careful study of the root system of the herbaceous vegetation is required.

Economic factors

Because of a cut in maintenance funding, cost reduction is the major motivation for stakeholders to change from current lawns to other alternative solutions (Paper II). According to the findings presented Paper I, the lawns were more expensive to establish and maintain in Chinese cities than in European cities for the import of mowing facilities, grass seeds and cost for more intensive maintenance The cost includes purchases of fertile peat soil for growing grasses, import of lawn mowers, irrigation facilities and grass seeds, petrol for mowing, costs for water, pesticides and fertilisers. The same findings were obtained from the study in Paper II, in which the cost of lawn establishment and maintenance were estimated by park managers in Xi'an.

Social-cultural factors

The conclusion was drawn in Paper I that the timing is currently right to develop sustainable lawn alternatives in China because the Chinese Environmental Policy of "Ecological Civilisation" is focused on eco-centrism. On the road to sustainable development, the relationship between humans and the environment in China will gradually change from ego- to eco-centric and emphasise a variety of ecosystem elements and their connection to the surrounding landscape.

The lawn provides few cultural services. Since the lawn was adopted to China from Western countries, no manicured lawns were used in the classical Chinese gardens as concluded in Paper I. Chinese people are educated not to step on the lawn to avoid damage to the grasses due to a large number of visitors, as part of the culture. Moreover, Chinese people do not like sunbathing and need more tree shade because they do not like getting tanned and want to look light (Zhang & Gobster, 1998). However, the requirement for tree shade from park visitors and the shade intolerance of grass species are controversial. The lilyturf (*Ophiopgon japonicus*), which is commonly used in classical Chinese gardens (Paper I), is highly recommended by stakeholders to grow in the tree shade (Paper II). It could also provide cultural services as a cultural symbol for its traditional use in classical Chinese gardens.

It was found in Paper II that the neatness of lawns are appreciated. Nevertheless, people could be educated to accept the messy biodiverse herbaceous vegetation. Previous studies have shown that biodiversity and environment-related attitudes positively influence the public perception of urban green spaces,

which could affect the management regimes employed (Gunnarsson et al., 2017; Knez & Thorsson, 2008). The stakeholders showed positive attitudes towards urban biodiversity as well as towards sustainability generally despite some misunderstandings, which will help them accept the alternative biodiverse herbaceous vegetation. Furthermore, park visitors also like flowering groundcovers for their colourful flowers (Paper II). It implies that herbaceous plants with colourful flowers could be used in future biodiverse herbaceous vegetation communities.

Existing alternatives to lawns were not suitable for the local environments as analysed in Paper II. For example, both Parterres and flower beds suggested by stakeholders in Xi'an are common elements of Western Baroque, Picturesque and Gardenesque landscape styles and contribute to the homogenisation of the urban flora (Ignatieva & Ahrné, 2013). Moreover, the perennial meadows with exotic plants and the wood sorrel (*Oxalis corymbosa*) groundcovers could pose a threat to the local environment due to the invasiveness of plant species used (Paper III).

The findings in Paper II and III showed that some of the proposed alternatives to lawns in other countries were not suitable for the context of Chinese cities. There is already plenty of research on lawn alternatives in the UK, USA, France, Sweden, Germany, Iran and New Zealand (Hoyle et al., 2017; Ignatieva et al., 2017; Müller, 1990; Simmons et al., 2011; Smith & Fellowes, 2014; Stewart et al., 2009). China has been following the trend from the 2000s (Paper I). For example, perennial meadows are currently suggested and used as one of the alternatives to lawns in Chinese cities including Xi'an (Hitchmough & De la Fleur, 2006; Hitchmough et al., 2013). However, in the analysis of Paper II, meadows were liked least by park visitors because they looked messy with the tall herbaceous plants used, which may be due to the different aesthetic expectation of Chinese people on the urban landscapes (Jiang & Yuan, 2017). Furthermore, according to findings presented in Paper III, the perennial meadows in Xi'an used non-native and even invasive plant species (e.g. *Coreopsis basalis*, *Oenothera rose*) (Yan et al., 2014). In some public parks of Xi'an city, clover lawns were initially applied as a substitute for turf lawns but later abandoned, because the white clover (*Trifolium repens*) had been listed as a serious invasive plant in China (Yan et al., 2014). The wood sorrel (*Oxalis corymbosa*) groundcovers were not suggested for its invasiveness and no pollinators were associated with it (Paper III). Therefore, the practical suggestions of sustainable lawn alternatives that fit into the Chinese context are urgently needed.

5.3 Theoretical contribution

5.3.1 Perceived vs actual provision of ecosystem services

One of the valuable contributions of this research is the evaluation and investigation of perceived (demanded) and actual (assessed) ecosystem services provided by lawns in Chinese cities. Some of the services elaborated on in the thesis were based on qualitative interviews, questionnaires and literature reviews showing stakeholders' perceived provision of ecosystem services by lawns, e.g., the provisioning services (refuge for disasters, safe place for children and adults, groundcover under the shade, heritage protection, aesthetic value, educational value) and regulating services (climate regulation, soil fixation, air quality regulation and water purification and treatment) as illustrated in section 5.1.3, Table 8. I found that there were mismatches between the perceived and actual ecosystem services provided by lawns. For example, the aesthetic (neatness and unified green colour) and ecological values of lawns were mostly appreciated by both park visitors and stakeholders (Paper II). However, the appreciation of the aesthetic value of lawns could be affected by the global dominance of idealised lawn aesthetics (Williams & Cary, 2002), which are alien to the Chinese traditional appreciation of nature. The overemphasis of the ecological values of lawns, such as climate regulation, and soil fixation, is probably due to the awareness of the environmental benefits of urban green spaces in general and could be provided by other herbaceous vegetation as well. Although lawns could provide certain environmental benefits, the detrimental effects from the intensive maintenance could also impair the environment as well as some ecosystem services. The understanding and addressing of those mismatched beliefs lies in the knowledge based on the assessment of social and ecological values of lawns. This research contributes to this knowledge.

Chinese people were found to have different perceptions of lawn values compared with people in other countries, although same core grass species as many other geographically distant cities were used as described in Paper III. For example, the social and recreational activities on lawns were appreciated by people from European countries such as Sweden (Ignatieva et al., 2017), while they are the least appreciated use of lawns in China because of particular social and cultural peculiarities.

5.3.2 The complexity of urban ecosystems

Urban biodiversity-ecosystem services relationships are more complex and modified due to the altered biotic and abiotic conditions and intensive human interferences, compared with those in non-urban contexts and controlled

experiments where a high incidence of biodiversity and ecosystem services have been found. For example, the intentional use of certain Western planting practices (e.g. lawns, perennial meadows with exotic plants in this study) resulted in the dominance of non-native plant species (which could also be invasive plants) in urban green spaces. The intensive management practices of lawns pose a threat to the local environment, which resulted in impaired ecosystem services (e.g. reduced native plants, reduced pollination, water contamination and consumption, carbon emission as illustrated in section 5.1.3). Nevertheless, some native species in urban areas facilitate the provision of certain ecosystem services (attraction of wild pollinators and educational values) according to Paper II and III. My research compared the delivery of UES by native and non-native species, which fills in a research gap (Schwarz et al., 2017). Although it is challenging to understand the relationship between biodiversity and ecosystem services in urban areas because of its complexity (Alberti, 2015), it is worthwhile to conduct research on it for its uniqueness.

5.3.3 The transdisciplinarity of the research

In the field of urban ecology, interdisciplinary and transdisciplinary research were proposed and a trend in terms of goals (sustainability-oriented), methods (from both natural and social sciences) and participants (scientists, practitioners, decision makers, and stakeholders of many kinds) (Wu, 2014).

Urban green spaces play an important role in sustainable development, which requires a more holistic research. Integrative approaches such as economic, political, social, cultural and management and planning aspects need to be considered to improve existing urban green spaces' facilities and services and related policies (Haq, 2011). This PhD project established a transdisciplinary research framework exploring sustainable urban green spaces in China by integrating Chinese landscape architectural traditions, social perceptions (stakeholders and park visitors) and ecological (biodiversity) perspectives. I applied the methodology from the disciplines of history, sociology and ecology. The process of research design, field work, data collection, data analysis and integration of the results were summarised and can be references for future interdisciplinary and transdisciplinary research on urban green spaces.

The theoretical framework adapted from theories of landscape sustainability works well in terms of examining the biodiversity and ecosystem services provided by lawns and other herbaceous vegetation in Chinese cities. Useful benchmarks and performance indicators were provided by the ecosystem services concept to link science with planning, design and management

(Ahern, 2013). Specifically, by analysing the factors that favour the provision of a suite of ecosystem services by lawns, suggestions could be made for planning, design and management based on the research results. This theoretical framework also applies to other types of urban green spaces. I replaced the concept of "landscape composition and configuration" in Wu's (2013) theory of "landscape sustainability" with "urban green spaces" and emphasised the importance of changing urban green spaces for the purpose of sustainability (providing eco-system services and meeting social needs and respecting societal values). Before planning, designing and managing urban green spaces, landscape architects need to fully understand the social-cultural, economic and environmental contexts of the local environment. There is a lack of that understanding when using lawns in non-European countries such as China, due to insufficient time before making decisions. This research in non-European countries as the latest adopters of lawns bridges this gap. In order to achieve the trade-off of multiple ecosystem services provided by herbaceous vegetation layers in Chinese cities, detailed suggestion on the planning, design and management of herbaceous vegetation were proposed according to the context (location, use and microclimate). Although challenges were recognised in applying sustainable lawn alternatives in Chinese cities, social-cultural, environmental and economic conditions in China presently encourage their implementation.

5.4 Future research: comments

It is challenging to combine natural and social sciences (Fischer et al., 2011) as they have fundamental differences in paradigms. For example, natural science usually takes an in-depth approach to answering a small question by using quantitative methods, while a broader approach with more qualitative methods is usually conducted in social sciences (Czech, 2002; Winchester, 1992). Replication of results is necessary in natural sciences, but this is not the case in social science as they may be impossible to replicate (Miller, 1994). Another difference is that natural sciences tend to adopt a positivist, reductionist approach looking for the truth, while in the social sciences, a more relativistic, holistic or social constructivist approach is taken (Borrego & Newswander, 2008). My educational background in ecology gave me a paradigm in natural science. The fundamental differences between natural and social sciences have brought difficulties for me in understanding and applying the methodology of social sciences in the beginning. Paradigm shifts and integration from natural sciences to social sciences were challenging for me. It required a lot of courses, discussions, readings as well as field work and communicating with

practitioners. Moreover, there were also difficulties in reinterpreting different methods and findings in social and ecological studies and incorporating them to answer my research questions. The trade-off of ecosystem services were mentioned in this thesis, but no specific methods were applied to analyse the trade-offs. This is due to the qualitative characteristics of cultural services and quantitative characteristics of ecological services. More work is required to explore the methods to link the ecological services and cultural services to offer more solid references for designing sustainable lawn alternatives.

Moreover, one of the strategies to enhance landscape architecture research and facilitate research findings into practical guidelines for effective landscape design and management, is to engage in transdisciplinary research by establishing and maintaining links to research communities outside of landscape architecture (Stokols, 2011; van den Brink & Bruns, 2014). Detailed and practical guidelines for sustainable lawn alternatives are required for local practitioners. This research offers references for such guideline making. The drought-tolerant, shallow root and trample-tolerant herbaceous species were suggested to use in the semi-arid climate, heritage parks and utility lawns respectively. But more research is needed by either consulting local horticulturalists or experimenting with the performance of different herbaceous plants from the local species pool.

During my interviews with stakeholders, I found that there was a knowledge gap between researchers and stakeholders in terms of theories and concepts as well as new tools and technologies from studies in landscape architecture (Paper II). This will significantly impact implementation of the research results. However, I also found that the stakeholders were attempting to apply ecology to their landscape projects, but lack the culture, the research skills and knowledge. Most of the planning and design proposals have included the terms "ecology" and "biodiversity", while they do not know what the terms mean or how they can be applied (Paper II). Therefore, the importance of involving stakeholders in the planning, conducting and implementing of landscape research cannot be stressed enough. This PhD work fosters communication among researchers and stakeholders (local politicians, urban planners, landscape architect, and city gardeners as well as park managers), park visitors of urban green spaces in China, by interviewing both stakeholders and park visitors. However, this was just an initiation of communication; further work, such as stakeholder meetings and local community meetings, are required to discuss designing and managing sustainable urban green spaces, which both enhance urban biodiversity and meet public needs.

In order to better transfer the research results, some strategies could be applied in the future. Firstly, demonstration sites in public parks are very

important as a way to display the research results. They could be firstly set in suburban areas as well as heritage parks. Secondly, stakeholders' involvement in the earlier stage of the research could be important. By communicating with stakeholders frequently and adjusting the research proposal according to their needs, the research results may be better accepted by them. There may also be a risk of being distracted by their thoughts and knowledge. Thirdly, adaptive design could provide an alternative scientific and professional strategy approach in which plans and policies are developed in a context of uncertainty and incomplete knowledge. Design proposals can then be structured as experiments to probe uncertainty, and test specific hypotheses. The ''safe-to-fail'' design experiments could be applied to scale down the experimentation sites and minimise the risk of failure (Ahern, 2011). Safe to fail design also holds the potential to rapidly advance professional knowledge and skills in direct association with the development and construction process itself.

This PhD project presumably strengthens the study on lawns worldwide by conducting transdisciplinary research. It also reveals the influence of lawns as an example of Western landscape design on the Eastern part of the world. It leads us to rethink the value of lawns (and in a wider sense urban green spaces inspired by Western landscape styles) in Non-western countries, whose culture is distinct from Western countries. The pathway towards sustainable urban green spaces requires contributions from a Chinese perspective and its philosophical roots of the "harmony of human and nature". However, nature needs to be redefined in people's minds, which is the ultimate goal of the transition to sustainable lawn alternatives.

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Popular science summary

The lawn is one of the most visible elements of urban green spaces and western landscape styles. As one of the latest adopters of lawns, China has seen a dramatic increase in yearly planted lawn area during the last 20 years. However, there is an urgent need for sustainable lawn alternatives in China due to the potential threats from intensive lawn maintenance to the already heavily contaminated environment and the cultural inadaptability of lawns. This thesis, via a case study in Xi'an City, attempts to examine the reasons behind the historical and current design and management of lawns in Chinese megacities and offers suggestions for sustainable lawn alternatives that are biodiverse, environmentally friendly and culturally acceptable from social-cultural and ecological studies on lawns.

In order to understand the driving forces of lawn development and their alternatives, a historical study on lawn development in urban green spaces of Chinese cities was conducted and Chinese and European examples of lawn alternatives were sought by reviewing literatures and doing field observations. Then, in order to understand stakeholder and park visitors' views on lawns and their alternatives and how their views affect their decisions in designing, managing and using lawns and lawn alternatives, stakeholders were interviewed, and data was collected using questionnaires and talking to park visitors and observing their activities on lawns. Furthermore, in order to find out how the design and management of lawns affects the environment in public parks and identify some potential plant species for creating sustainable lawn alternatives, plant species in lawns as well as other common herbaceous vegetation types and pollinator species were inventoried.

The results indicate that classical Chinese gardens did not contain mono-culture and large-scale grassy surfaces. The lawn was introduced to China after the 1840s when foreign residents were allowed to live in some treaty port cities, such as Shanghai. After the 1980s, with the trend of globalization, the lawn became an essential element of urban green spaces in China. We can see

from classical Chinese gardening that herbaceous plant species were used according to their suitability to site conditions, which enriches the diversity of species and is therefore inspiring for sustainable lawn alternatives. Furthermore, the lawn in Chinese cities has the same exotic grass species as many other cities worldwide. In Chinese cities, lawns, perennial meadows with exotic plants and wood sorrel could be potential sources of invasive species. Native resources of herbaceous plant species need to be explored as a substitute for the exotic species used in those vegetation types in order to protect the local environment. The intensive management practices of lawns reduce plant species diversity and the spontaneous growth of native species in them. In older, larger lawns and more planned green spaces in the urban area, plant species and spontaneous native species in lawns are more diverse. Pollinators could be attracted by the flowers of some spontaneous native plant species in lawns, but this can only occur when maintenance is minimised. It was found that park visitors and stakeholders preferred neat lawns over perennial meadows and lilyturf groundcovers. However, this explains why lawns are frequently and intensively maintained. They also appreciate the ecological benefits of lawns such as air purification, soil fixation and climate regulation. Nevertheless, it seems that stakeholders and visitors are unaware of the potential environmental problems caused by rigorous lawn maintenance. Moreover, in China people have limited access to lawns. Thus people can hardly benefit from using lawns for recreational activities and building social relations. As a symbol of western culture, the lawn fails to reflect Chinese culture in public spaces. Concrete recommendations for sustainable lawn alternatives for Xi'an and China are proposed, although it was found that there are challenges to changing current lawn design and management. Regardless, the study concludes that it is possible to implement biodiverse lawn alternatives according to current social-cultural, environmental and economic conditions in China.

Populärvetenskaplig sammanfattning

Gräsmattan är ett av de mest synliga elementen inom urbana grönområden och västerländsk landskapsstil. Bland de senaste länderna som anammat gräsmattor finns Kina, där det under de senaste 20 åren skett en dramatisk ökning av arealen gräsmatta som anläggs per år. Det finns dock ett akut behov av hållbara gräsytor i Kina på grund av de potentiella hot som en intensiv skötsel av gräsmattor utgör för den redan starkt förorenade miljön, samt den brist på kulturell anpassning som utbredningen av gräsmattor innebär. Denna avhandling försöker genom en fallstudie i Xi'an City, undersöka orsakerna till den historiska och nuvarande utformningen och hanteringen av gräsmattor i kinesiska storstäder samt ge förslag på hållbara alternativ till gräsmattor, vilka tillhandahåller biologisk mångfald, är miljövänliga och kulturellt acceptabla utifrån sociokulturella och ekologiska studier.

För att förstå drivkrafterna bakom gräsmattans utveckling och dess alternativ, genomfördes en historisk studie om gräsmattans utveckling i urbana grönområden i kinesiska och moderna europeiska städer, där kinesiska exempel på alternativa gräsytor söktes genom litteraturstudier och fältobservationer. För att förstå olika intressenters och parkbesökares perspektiv på gräsmattor och dess alternativ samt hur deras syn påverkar deras beslut när det gäller utformning, hantering och användning av gräsmattor och alternativa gräsytor, genomfördes intervjuer med intressenter, samlades data in med hjälp av frågeformulär, fördes samtal med parkbesökare och gjordes observationer av deras aktiviteter på gräsmattorna. För att få reda på hur utformningen och hanteringen av gräsmattor påverkar miljön i offentliga parker samt identifiera potentiella växtarter för att skapa hållbara alternativa gräsytor, inventerades dessutom växtarter i gräsmattor liksom i andra vanliga örtartade vegetationstyper samt arter av pollinerare.

Resultaten tyder på att klassiska kinesiska trädgårdar inte innehöll mono-kulturer med stora gräsbevuxna ytor. Gräsmattan introducerades i Kina efter 1840-talet när utländska medborgare fick tillstånd att bosätta sig i vissa hamnstäder, till exempel Shanghai. Efter 1980-talet, med globaliserings-

utvecklingen, blev gräsmattan ett viktigt element i urbana grönområden i Kina. Vi kan se att i klassisk kinesisk trädgårdsskötsel användes örtartade växtarter utifrån deras lämplighet för förhållandena på platsen, ett förhållningssätt som berikar mångfalden av arter och därför är inspirerande för utformningen av hållbara alternativ till gräsmattor. Dessutom innehåller gräsmattor i kinesiska städer samma exotiska gräsarter som i många andra städer över hela världen. I kinesiska städer kan gräsmattor, ängar med fleråriga exotiska växter och harsyreväxter bidra till att invasiva arter etableras. I syfte att skydda lokala miljöer behöver man undersöka om de inhemska resurserna i form av örtartade växtarter kan ersätta de exotiska arter som används i dessa vegetationstyper. Den intensiva skötseln av gräsmattor minskar mångfalden växter och den spontana tillväxten av inhemska arter i dem. I äldre större gräsmattor och mer planerade grönområden i stadsmiljöer är mångfalden växtarter och inslaget av spontant förekommande inhemska arter större. Pollinerare kan lockas av blom-morna hos vissa spontant förekommande inhemska arter i gräsmattor, men detta sker endast om underhållet minimeras. Det kan konstateras att parkbesökare och intressenter föredrog prydliga gräsmattor framför ängar med perenner och marktäckare som druvlilja. Detta förklarar dock varför gräsmattor underhålls så ofta och intensivt. De ekologiska fördelarna med gräsmattor som luftrening, markfixering och klimatreglering uppskattades också. Ändå verkar det som om intressenter och besökare är omedvetna om de potentiella miljöproblem som orsakas av en rigorös skötsel. I Kina har människor dessutom begränsat tillträde till gräsmattorna. Det innebär att de knappast kan nyttja gräsmattorna för fritids-aktiviteter och socialt umgänge. Som en symbol för västerländsk kultur, miss-lyckas gräsmattan med att avspegla den kinesiska kulturen i det offentliga rummet. Konkreta rekommendationer för hållbara alternativ till gräsmattor för Xi'an och Kina ges, även om det kan konstateras att ligger en utmaning att försöka förändra nuvarande utformning och skötsel av gräsmattorna. Oavsett detta, dras slutsatsen att det är möjligt att introducera alternativa gräsytor med biodiversitet i enlighet med dagens sociokulturella, miljömässiga och ekonomiska förhållanden i Kina.