

Towards Sustainable Green Infrastructure in Xi'an, China

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*Linda Johansson and Victoria Smårs
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SUMMARY

One of the greatest challenges of today's society is to achieve sustainable urban development. China is a big country with the largest population in the world, which is growing even more, and so do the already large cities. Pollution is a big problem in the cities in China, hence, it is very important that plans for green infrastructures in the cities are encouraged. Green areas can help to mitigate the pollution, they have a whole range of ecosystem services and they play an important role in creating a healthy urban environment.

This master thesis concerns the green infrastructure in the city of Xi'an, the former ancient capital of China. The aim is to study the green infrastructure in three different scales; from the overall city plan via intermediate neighborhood to the fine solution for a green area of a specific site. The results are based on sustainability from an ecological and social perspective. The results could be used as a tool for suggesting a strategy for the development of sustainable green infrastructure in Xi'an and other Chinese cities.

The work with this master thesis consisted of four phases; preparation and research, a field study, compilation of the gathered material and final proposal and presentation. Methods that were used during the inventory were literature study, studies of maps and plans, case study of a neighborhood, site visits, field trips, interviews, observational studies and photography. SWOT-analysis and Lynch-analysis were methods used to analyze the sites. The methods were used to get as wide perspective of the city as possible.

Green infrastructure is a network of the green areas in a city and its surroundings. It provides several benefits to people and wildlife with its ecosystem services, health aspects and social values, whether it is large scale or small scale. To protect and restore the green infrastructure in the growing cities is thus essential.

Western influences, such as lawns and flowerbeds, are commonly seen in the green infrastructure of Xi'an. Especially in green areas inside neighborhoods and in front of historical monuments, campuses and governmental institutions, such elements are common. The western influences are not adjusted to the Chinese culture or local conditions though, resulting in very high maintenance and bad impact on the environment. Even modern green areas have classical Chinese elements; they have lost their initial spiritual meaningfulness and have mostly functional purpose. This phenomena need to be evaluated and discussed further on.

This master thesis could be a small step towards a beginning of improving green areas and the living conditions in bigger cities in China.

SAMMANFATTNING PÅ SVENSKA

Xi'an ligger i det östra inlandet i provinsen Shaanxi och var under flera decennier Kinas forntida huvudstad. Tre tusen år gammal historia finns bevarat i staden, bland annat den autentiska planeringsstrukturen. På senare år har även många västerländska planeringsprinciper applicerats, exempelvis gräsmattor och färgglada sommarplanteringar.. Staden har cirka 8,5 miljoner invånare idag (2015), men en exponentiell ökning fortskrider. Detta betyder att det är väldigt viktigt att ha en plan för en hållbar stadsutveckling.

Kina är idag världens största luftförorenare på grund av den snabba tekniska utvecklingen och ekonomiska tillväxten som skedde i landet. Medvetenheten om att hänsyn måste tas till de gröna områdena i städerna har ökat på senare år. De spelar en viktig roll i skapandet av en hälsosam stadsmiljö med dess förmåga att mildra föroreningsgraden i luften, men även för dess ekologiska, sociala, kulturella, estetiska och rekreativa värden. Utvecklingen av grönstrukturen i städerna på ett hållbart sätt är därför viktig, exempelvis genom ekologisk design.

Syfte och mål

Syftet med det här examensarbetet är att i olika skalor studera grönstrukturen i staden Xi'an i Kina, från den stora övergripande stadsplanen (Big Scale) via ett mindre stadsdelsområde (Intermediate Scale) och sist till den detaljerade designlösningen av en konkret plats (Small Scale). Resultatet av denna studie kan användas som ett verktyg att föreslå en strategi för hållbar grönstrukturutveckling i Xi'an, men som också kan bli applicerade i andra städer i Kina. I det detaljerade designförslaget ligger fokus på ekologiska designlösningar med ”Low Impact Design” och dess tillämpning för de lokala förhållandena i Xi'an. Detta är ett litet steg mot början av en förbättring av grönytor och levnadsvillkoren i större städer i Kina.

Metod

Detta examensarbete har gått igenom fyra faser; förberedelser och efterforskning, en fältstudie, sammanställning av insamlat material och slutligt förslag och presentation. Metoder som användes under inventeringen var litteraturstudier, studier av kartor och planer, fallstudie av ett bostadsområde, platsbesök, studieresor, intervjuer, observationsstudier och fotografering. SWOT och Lynch var metoder som användes för analys av platserna, detta för att få ett så brett perspektiv av staden som möjligt.

Urban grön infrastruktur

Grönstrukturen skapar en helhet i staden och bidrar till betydelsefulla ekosystemtjänster. Den har positiv inverkan på biodiversiteten, miljöförhållandena, ekonomiska aspekter och sociala värden; så som hälsa. Termen grön infrastruktur är ganska ny, men inte dess koncept. Den har sitt ursprung i två grundläggande initiativ; dels att skydda och sammankoppla parker och andra gröna områden till fördel för människorna men också att bevara och sammankoppla naturliga ytor för att gynna biodiversiteten och motverka habitatfragmentering.

Planering för grön infrastruktur måste planeras med stor kunskap för att uppnå en hållbar stadsutveckling. Dagens förtätning i städerna är ett hot mot grönstrukturen och på senare tid har den minskat och blivit allt mer fragmenterad. Detta ger även konsekvenser för den lokala dagvattenhanteringen, luftkvaliteten och det lokala klimatet. En grönstrukturplan kan vara ett verktyg i planeringsprocesser för att skydda och utveckla grönytor i städerna.

Ekologisk design

För att reducera den mänskliga påverkan på vår planet är ekologisk designplanering i städerna något att eftersträva. Det har blivit betydligt viktigare än tidigare, i och med ökade bevis på klimatförändringar

orsakade av människan har medvetenheten blivit större och även oron för framtida effekter har ökat. Med en ekologisk designlösning ökas den ekologiska funktionen och mångfalden bland arter, även resursförbrukningen minskar. Konstruktionen syftar till att efterlikna eller återskapa det naturliga systemets cykliska mönster, vilket stödjer en hållbar utveckling och förnyelse över tiden.

”Low Impact Design” är en ekologisk designmetod som hanterar dagvatten i städerna på ett miljömedvetet sätt. Exempel på ”Low Impact Design”-lösningar är bland annat rain gardens, gröna tak och gröna väggar. Dessa fördröjer och renar vattnet men ökar även den biologiska mångfalden, renar luften genom absorbering av luftföroreningarna och sänker temperaturen i städerna. De skapar miljöer som respekterar, bevarar och förbättrar de naturliga processerna.

Klassiska kinesiska trädgårdar

De klassiska kinesiska trädgårdarna har haft inflytande på parker och trädgårdar över hela världen. Målningar och dikter om naturen är ideal som ligger till grund för den kinesiska trädgårdsdesignen och inspiration kommer huvudsakligen från naturens egna former. Vanligt förekommande element i en kinesisk trädgård är stenar, vattnelement, paviljonger, slingrande gångar och pagoder. Bambu, tall, pioner, pilträd och blommande körsbärsträd är vanliga växter i dessa trädgårdar. Väggar och murar används ofta som bakgrund till dessa för att fånga kalligrafiska mönster från skuggorna.

Confucius, Lao Zi och Buddha är de tre filosoferna som gav upphov till religionerna Konfucianism, Daoism and Buddhism. Dessa läror är grunden för att förstå varför de kinesiska trädgårdarna ser ut som de gör och vad man egentligen ser.

Big Scale

Den gröna infrastrukturen i Xi'an är väldigt fragmenterad i dagsläget och utan koppling till varandra. I den här fallstudien identifieras och utvärderas stadens grönområden och delas in i olika kategorier. Med hjälp av analyser tas riktlinjer fram för att med hjälp av dessa kunna utveckla grönstrukturen i staden på ett ekologiskt hållbart sätt. Genom att utveckla gröna korridorer i staden och koppla samman stadens grönska med landsbygden bildas kopplingar mellan grönytorna. I och med det ökar de ekologiska värdena då spridningen för djur och växter förenklas. Då det finns lite plats att expandera eller anlägga nya grönytor inne i staden är det viktigt att bevara och ta hand om den redan existerande grönskan, bland annat genom att använda sig av inhemska arter och ekologiska designlösningar. Gröna tak och gröna väggar är exempel på ekologiska designlösningar som kan användas för att öka grönfaktorn i staden trots den täta bebyggelsen.

Intermediate scale

För att ta reda på hur man mer specifikt kan utveckla grönytorna på ett ekologiskt hållbart sätt i Xi'an studerades ett mer inzoomat område; bostadsgården Rongcheng. Riktlinjer togs fram som även skulle kunna appliceras på andra liknande bostadsområden.

Rongcheng är en väldigt grön bostadsgård men med västerländska influenser som inte riktigt kommit till sin rätt, högt underhåll och ett ekologiskt hållbart perspektiv saknas vad gäller olika lösningar. Större gräsmattor skulle kunna ersättas med marktäckare, dels för att öka biodiversiteten men också för ett lättare underhåll. Smala gräsremсор som finns längs gångvägarna har ofta dålig tillväxt och fyller ingen funktion, att plantera marktäckare eller buskar skulle vara ett alternativ. Dammen på gården skulle kunna omvandlas till en dagvattendamm för att ta hand om överflödigt regnvatten, även vattnets kvalitet kan höjas med ökad cirkulation. Parkeringsplatser som inte används har stora möjligheter att bli mer ekologiskt inriktade, exempelvis genom att omvandlas till rain gardens.

Small scale

I Small scale kapitlet utvecklas idén från Intermediate scale om de tomma parkeringsplatserna i Rongcheng. Idén är att omvandla dessa till sociala ytor med en ekologisk hållbar inriktning. Designförslaget, Social Rain Garden, är en rain garden kombinerad med plats för sociala aktiviteter. Designen är inspirerad av den kinesiska kulturen och de klassiska trädgårdselementen finns med så väl som inhemska arter.

Diskussion

Syftet med denna studie var att studera grönstrukturen i Xi'an i tre olika skalor ur ett ekologiskt och till viss del socialt hållbart perspektiv för att kunna ta fram riktlinjer om hur den skulle kunna utvecklas. Resultatet indikerade att dagens gröna infrastruktur i Xi'an var fragmenterad och tillgodosåg inte stadens ekosystemtjänster. En hållbar grönstrukturplan var på väg att arbetas fram, detta för att undvika den expansion av staden som sker nu utan en plan för grönytornas utveckling. Gröna tak, gröna väggar och att utöka grönskan längs vägarna är alternativ för att koppla ihop grönstrukturen i den befintliga staden, det krävs dock platsspecifika lösningar för varje grön länk.

Viljan hos kineserna att införa mer gräsmattor kan diskuteras. De kräver mycket skötsel och underhåll och är inte det bästa valet för att förbättra de ekologiska aspekterna. Det är ett relativt nytt koncept och inte anpassat till de lokala förhållandena. I framtiden har kunskapen om gräsmattor och dess anpassning till kinesiska förhållanden förmodligen förbättrats vilket gör att de kan underhållas på ett mer medvetet och hållbart sätt.

Element från klassiska kinesiska trädgårdar fanns även i de moderna trädgårdarna. Det som dock skiljde sig var att de ursprungliga materialen ersatts av konstgjort material; stenarna var gjorda av betong och ibland användes plastväxter. Många detaljer i bland annat paviljonger och korridorer hade även fallit bort i de moderna

trädgårdarna. Kanske är det detta som gör att de moderna kinesiska trädgårdarna har tappat sin andliga ådra vilket Chen (2013) och Ignatieva et al. (2015) konstaterat.

Kina är medveten om sina miljöproblem och vet att de måste göra något åt dem. Förhoppningsvis kan framtiden bjuda på värdefulla utbyten mellan lyckade fältstudier om grönstrukturen ur både österländska och västerländska perspektiv.



DEFINITION AND ABBREVIATIONS

This part shows definitions of used terms in this master thesis.

Biodiversity

Biodiversity is the variability among living organisms on earth. It includes both the diversity within and between species as well as within and between ecosystems (Benedict & McMahon 2006).

Corridor

A linear or narrow segment of land that differs from the environment on each side and could serve as biological or hydrological linked corridors and/or provide outdoor, recreational opportunities (Benedict & McMahon 2006).

Ecological design

Ecological design aims to adapt the environment and improve ecological functions, create a more resistant design and management of the built environment, and seeks to understand the relationship between organisms and nature as well as resources for human use, which thus support sustainable development (Rottle 2010).

Ecosystem

The living and nonliving components of the environment that interact, including native plants, animals, humans, physical environment and energy systems (Benedict & McMahon 2006).

Ecosystem services

Nature's functions can be described as services that nature does to humans. For example the greenery purifies air and water and contributes to biodiversity (Boverket 2014).

Greenbelt

A connected network or belt of nature or farmlands that surrounds the city and buffers areas beyond the city from urban and suburban growth (Benedict & McMahon 2006).

Green infrastructure (GI)

Green infrastructure is a collective term which comprises all the vegetation areas in the city and in its surroundings. It includes parks, housing estates, churchyards, colony areas, roadsides and private gardens (Butch & Persson 1994). A network of the natural areas and open spaces that surround and penetrate the city (Rottle 2010). In this thesis we also use green structure as a synonym to green infrastructure.

Green infrastructure network

A physical network that links green areas and other types of open spaces together to preserve natural functions and protect the species living there (Benedict & McMahon 2006).

Green infrastructure plan

A green infrastructure plan identifies green infrastructure resources in a community, region or state, in terms of ecological value, vulnerability, benefits etc. It describes methods to protect, restore and maintain those resources in favor of nature and human and can thereby help in determining where conservation and development should take place (Benedict & McMahon 2006).

Green links

A coherent green infrastructure in the city that works as vegetation corridors and are important for the biological diversity (Formas Miljöforskning 2015).

Green space

Examples of green space could be natural areas, parks, greenways, trails etc. Green space can preserve natural ecological functions and values and provide places for recreation (Benedict & McMahon 2006).

Greenway

A linear open space or park designed as a parkway or greenbelt, established along for example natural corridors, river fronts, railroads, canals, walking paths etc. (Benedict & McMahon 2006).

Habitat

An organism's natural environment that contains elements of a landscape that is essential for the plant or animal survival (Benedict & McMahon 2006).

Habitat fragmentation

Human activity such as road building, land development, agriculture etc. creates small, isolated areas, poorly able to maintain ecological functions and to support the remaining of smaller populations (Benedict & McMahon 2006).

LID

Low Impact Design – a program for an alternative way to design and develop the urban areas with nature in a more cost-effective way. LID conserve, respect and enhance natural processes (Ignatieva et al. 2008).

Link

Or green link, is the connection that enables a system or network to operate and by a connection, it enlarges the utility of existing landscape components. It is often considered synonymous with corridor (Benedict & McMahon 2006).

Rain garden

A plant bed with the purpose of infiltrate storm water from hard paved surfaces nearby. This permeable surface will delay and clean the water (Veg Tech 2015).

Storm water management

Dealing with quantity and quality of storm water run-off is termed storm water management. Conventional storm water management means that water run-off is collected into the sewage system. Nowadays sustainable storm water management is on the agenda, which seeks to find ecological approaches of storm water management such as bio swales and rain gardens. Sustainable storm water management will be increasingly important with urban expansion (Svenskt vatten P105 2011).

Sustainable development

A process in constant change in consideration of the environmental sustainability given the local and regional conditions (Boverket 2015).

Urban ecological network

Landscape connectivity, physical and ecological connections between built-up areas of the city and surrounding natural areas, particularly in the forms of wildlife movement corridors and stepping stones, incorporate higher quality linkages between habitat patches (Ignatieva¹).



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INTRODUCTION

This chapter contains an introduction of the subject and the intention with this master thesis. It describes propose and scope and previous scientific research as well as thesis disposition.

INTRODUCTION

One of the greatest challenges of today's society is to achieve sustainable urban development. China is the world's most populated country with a large number of big cities. The population is growing exponentially (Wang 2007). With an increasing population comes a densification of the city, at the expense of green areas, which makes it very important to have a plan for the sustainable urban development, organization and management of new and existent green areas in the cities (Bucht & Persson 1994).

China has invested in rapid technological development and a huge economic expansion. This may cause a health hazard for the country's 1.34 billion citizens due to pollutions and emissions of carbon dioxide. According to American estimates, China's carbon dioxide emissions are increased by a corresponding whole Germany's annual emissions, which is most of all countries in the world. China is thereby the world's biggest polluter (Brander 2011).

To achieve a sustainable urban environment, the cities need a development of green infrastructure. Green areas have a whole range of ecosystem services (such as better air quality, storm water drain, climate regulator, pollination etc.) and play an important role in the creating of a healthy urban environment (Sorte 2005). Besides mitigating the air pollution, taking care of the urban storm water and providing habitat for flora and fauna, green infrastructure also has a positive impact on our health (Bucht & Persson 1994).

According to Van Der Ryn & Cowen (1996), we are in a great need to effectively start to interweave human and natural design of green areas. One way of doing that is to implement different types of ecological design solutions in the urban environment. Ecological design aims to resemble the natural environment, improve ecological functions (such as ecosystem services) and create a resistant design of urban space (Rottle 2010). By adapting natural processes in the design, maintenance

is also reduced (Dunnette & Hitchmough 2004). Ecological design, thus, reduce human impacts on the planet and support sustainable development and regeneration over time (Van Der Ryn & Cowen 1996). One method of ecological design is Low Impact Design (LID), which aims to respect, preserve and improve the nature's processes in a cost-effective way (Ignatieva et al 2008). Different types of ecological design approaches applicable in cities are for example rain gardens, green roofs and green walls (vertical gardens).

Xi'an is an old city with approximately 8.5 million inhabitants in 2015. The city was once the ancient capital of China. Xi'an has a lot of preserved features of authentic planning structure which makes this city a unique case study. It has history of more than three thousand years; from the empire dynasty, to democratic revolution and finally to the era of globalization. Nowadays it is applying different western principles of planning and landscape architecture which need to be evaluated and discussed concerning sustainability (Ignatieva, M., Xiu, N. & Yang, F. 2015).

Classical Chinese gardens, based on the philosophy of Taoism, Confucianism and Buddhism, were the dominant type of green space in Chinese cities for about 2000 years. Rocks, water bodies, bridges and pavilions are examples of classical Chinese garden elements (Sirén 1948). Western elements of green spaces, such as flowerbeds and lawns, are quite new concepts in Chinese cities (Ignatieva et al. 2015). They were introduced first in 1839-1842 during the First Opium War. But it was not until the Chinese Economic Reform in 1978, that the use of Western elements of green infrastructure escalated. The new trend though, did not take into consideration the different climatic conditions or local cultural conditions, according to Chen (2013). Nobody was, nevertheless, embarrassed by the high maintenance cost, pollution from mowing, cutting and watering or the low biodiverse values that these elements contributed to. Instead it can be seen as a

symbol of success of the Chinese market economy model (Ignatieva et al. 2015).

However, reduction of air pollution is one of the main functions of all green spaces in Chinese cities. Even a small green area contributes with great values to the physical and spiritual health of Chinese urban environment, according to Ignatieva et al. (2015).

Disposition

This master thesis is divided into four different chapters: background, method, results and discussion. First there is an introduction to the thesis with aims and research questions. Then the used methods are described in detail, and it is followed by background information regarding green infrastructure, China and Xi'an. Afterward there is a chapter with the results from big scale, intermediate scale and small scale approach and from the interviews. In the last chapter the results are discussed combined with reflections and further research questions.



Purpose and scope

The aim of this master thesis is to study the green infrastructure in the city Xi'an in China in different scales; from the overall plan via intermediate neighborhood to the fine solution for a concrete green area of a specific site. Results of this study could be used as a tool for suggesting a strategy of sustainable green infrastructure development in Xi'an which also could be applicable to other cities in China. The focus of fine scale design will be on ecological design approaches particularly Low Impact Design and its application to the local Xi'an's conditions. This could be a small step towards a beginning of improving green areas and the living conditions in bigger Chinese cities.

Research questions

- What are the main features of Xi'an green infrastructure?
- What ecological approaches can be applied to support a development of sustainable green infrastructure in Xi'an on different scales?

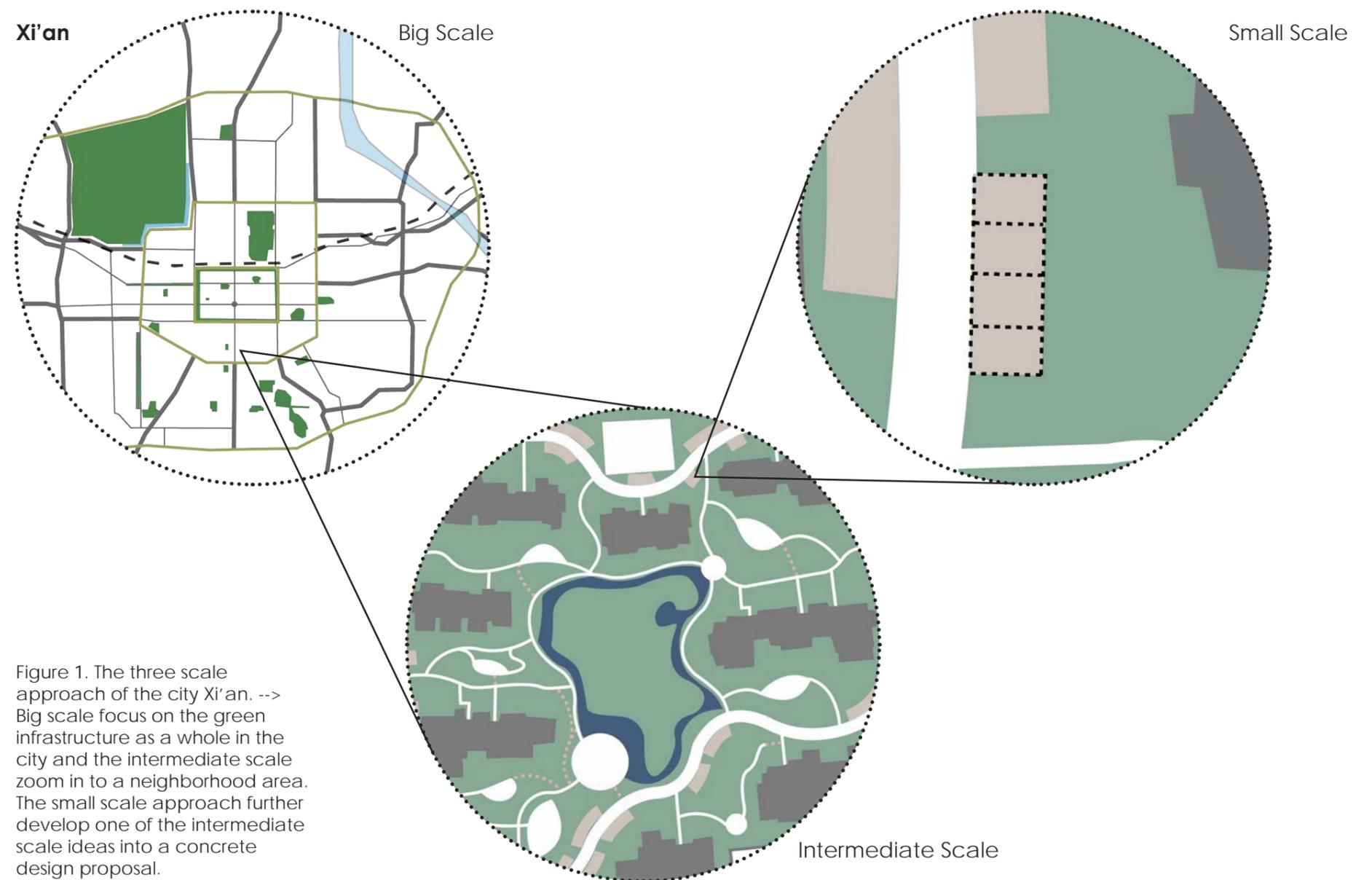


Figure 1. The three scale approach of the city Xi'an. --> Big scale focus on the green infrastructure as a whole in the city and the intermediate scale zoom in to a neighborhood area. The small scale approach further develop one of the intermediate scale ideas into a concrete design proposal.

Limitation

The study was limited geographically to the city Xi'an in China and thematically to the green infrastructure in the city. The case study is further limited to three scales; big, intermediate and small scale. Most focus has been dedicated to the intermediate scale. The big scale is limited to the green infrastructure in Xi'an within the 3rd Ring road. It also aims to present guidelines, not a fully proposal in detail, for the green infrastructure development. The intermediate scale is restricted to one neighborhood in Xi'an with the intention to produce guidelines for how the green areas in the neighborhood could be further developed with different ecological design solutions. The small scale is further constrained to present how one of the suggested solutions in intermediate scale could appear.

The Chinese language was a limitation for us when it comes to interviews; hence, an interpreter was needed. The time set for the field study was also a constraining factor for this master thesis. Inventories were made in public parks, streets, neighborhoods, environments next to campuses and governmental institutions, plazas in front of historical monuments and cemeteries. Brownfields, riversides, and railway wedges were excluded due to time limitation.

Target group

The target group is primarily landscape architects, city planners, politicians and students in China and other countries with similar geographical and climate conditions as in Xi'an. It could also be of interest for such professions in western countries in the search for sustainable green infrastructure in bigger cities in particular.

Previous scientific research

A majority (97%) of climate scientists agree that climate-warming trends over the past century are very likely due to human activities (Nasa 2015). It is thus of great importance that we find sustainable solutions for city development.

Increasing awareness of ecology has become a contemporary trend in both landscape architecture and landscape architecture education (Stewart et al. 2007). Beside lower cost for pollution control and water infiltration, green infrastructure also have positive impact on the economic value of properties in the city (Ignatieva¹).

There are numerous publications that confirm the ecological, social, cultural, aesthetic and recreational benefits from green areas (Ignatieva et al. 2010). Green areas have further over the last century been an essential component of town and city planning. For China though, urban green space planning and development are a very new concept (Chen 2013). Less than a century ago, green areas in China were private, privileged and landscape-miniatures all over, based on the thousand-year-old tradition of private gardens. Further stresses that the alteration seen in the 20th century in Chinese cities is still progressing.

After 1949, Soviet and Maoist thinking drastically changed the status of urban green space, when economic growth and innovative ideas of a new communist urban life were brought up. Another central change occurred during the 1980s and 1990s after the outline of Chinese market economy model, when green space were seen as an opening to improve city images internationally and meet the local increasing call for recreation, public health and quality of life according to Chen (2013). Today, worldwide, global awareness is stimulated and big efforts are made to bring environmental problems under control (Van Der Ryn & Cowen 1996). It has resulted in more large-scale and incorporated functions for resource management regionally. However, there is no

wide-ranging agreement or specific description of elements that should be included in green space planning (Chen 2013).

There are Chinese studies about urban green space planning history, some specific aspects of urban planning, about land use and urban development, urban design principles, practices and planning ideologies (Chen 2013, Zhao 2009, Yi 1993). There has been few researches though (if any), regarding analyzes of sustainable green infrastructure and ecological design implementation in Xi'an. The main contributions of this study consist of providing an understanding of the overall green infrastructure of Xi'an and how different ecological approaches can be applied in this particular case.

¹ Maria Ignatieva, Professor in Landscape Architecture, Swedish University of Agriculture Science, lecture 2015-02-25.

The background of the page features a soft-focus photograph of traditional Chinese lanterns hanging from thin wires. On the left side, the dark green, needle-like branches of a large tree are visible against a pale, overcast sky. The lanterns are of two types: some are circular with a vibrant, multi-colored radial pattern, while others are solid red and spherical with a textured surface. The overall atmosphere is calm and celebratory.

METHODOLOGY

This chapter describes the methods that were used during the work with this master thesis. There is also a presentation of the persons who were interviewed and associated questions.

The work with this thesis has passed through four major phases; preparation and research, field study, compilation of gathered material and final proposal and presentation.

METHODOLOGY



Literature study

In the preparatory research in advance of the field study a lot of books were read about China and Xi'an, both in English and Swedish, as well as literature regarding different green infrastructure plans. The conducted literature survey was required to understand the history, economy, political context, culture, planning structure and to become familiar with different types of green areas in Chinese cities. Thereafter the focus was set on local environmental peculiarities, green infrastructure, ecological design and specifically Low Impact Design (LID). Background material was also found on the internet via Google, Google Scholar, Epsilon and Libris. Keywords used were for example green infrastructure, green space, green areas, green infrastructure plan, ecological design, sustainable development, China and Xi'an, both in English and Swedish. Most relevant information was obtained from the English sources.

Studies of maps and plans

Inventory work of city maps and green structure plans of Xi'an were made before the field trip. In China it is difficult to have access to local urban maps and plans due to restrictions and security (Ignatieva¹). Therefore all maps and plans that we could possibly use were gathered in Sweden in advance.

Google maps: Contemporary maps of Xi'an from Google were used as a basis for our inventory of the big scale approach of green infrastructure. Source: <http://www.google.se/maps>

Baidu maps: We also used contemporary maps of Xi'an from Baidu, the Chinese version of Google maps, and compared it with Google maps. By using two different sources we gained a better understanding of the green infrastructure and a more reliable result. Source: <http://map.baidu.com/>

Municipal maps: Municipal maps were studied as well, such as a plan for the green infrastructure in Xi'an, today's land use planning and a zoning map. Source: Xi'an City Planning Bureau 2007.

Tourist maps: These maps were a big help for the general understanding of the city's structure and composition. They were also used to identify parks and other elements in the city.

Field study

The visit in Xi'an was a central part of this master thesis. The field study lasted for eight weeks (16th of March to 10th of May). The Minor Field Study scholarship from SIDA made the field trip possible.

In the course of these eight weeks a big part of the inventory and analysis were accomplished as well as documentation, observations and interviews. We visited several public parks; recreational, historical and for ecological demonstration (see table 1), neighborhoods from different eras and classical Chinese gardens to gather inspiration and get a picture of how they are used and to understand their structure. The criteria for the studied parks were that they should be both big and small, from different eras and with a convenient distance from the city center. To get an even wider picture of the main features of Xi'an green areas, as much green spaces as possible were visited and documented and further clarified into different categories. For explanation of the categories see page 45.

During those eight weeks we also began to sketch out some ideas for the proposal. At first we discussed what types of ecological design solutions that could be applicable in intermediate scale and then we discussed, based on our observational study, where we could implement the different new ecological solutions. Then we decided which type of ecological design solution to use in the small scale proposal.

Table 1. Studied public parks in Xi'an. See page 44 for the location of the parks.

| Recreational Parks | Historical Parks | Ecological demonstration Parks |
|-----------------------------------|--------------------------------------|--------------------------------|
| Children's Park | Daming Palace National Heritage Park | Hangcheng Lake |
| City Wall Park/ Huancheng Park | | Chanba National Wetland Park |
| Tang Paradise | | Sponge Park |
| Lianhu Park | | |
| Geming Park (Revolution Park) | | |
| Xingqing Palace Park | | |
| Xi'an City Sports Park | | |
| Qujiang Lake Heritage Park | | |
| Tang Dynasty Wall Relic Site Park | | |
| Xi'an Botanical Garden | | |
| Marty's Cemetery | | |

¹ Maria Ignatieva, Professor in Landscape Architecture, Swedish University of Agriculture Science, lecture 2015-02-25.

Case study neighborhood

A case study is an empirical inquiry with a major purpose to understand a specific case. It aims to study a contemporary defined phenomenon with different methods. A case study is always analyzed in their natural context. (Johansson 2000)

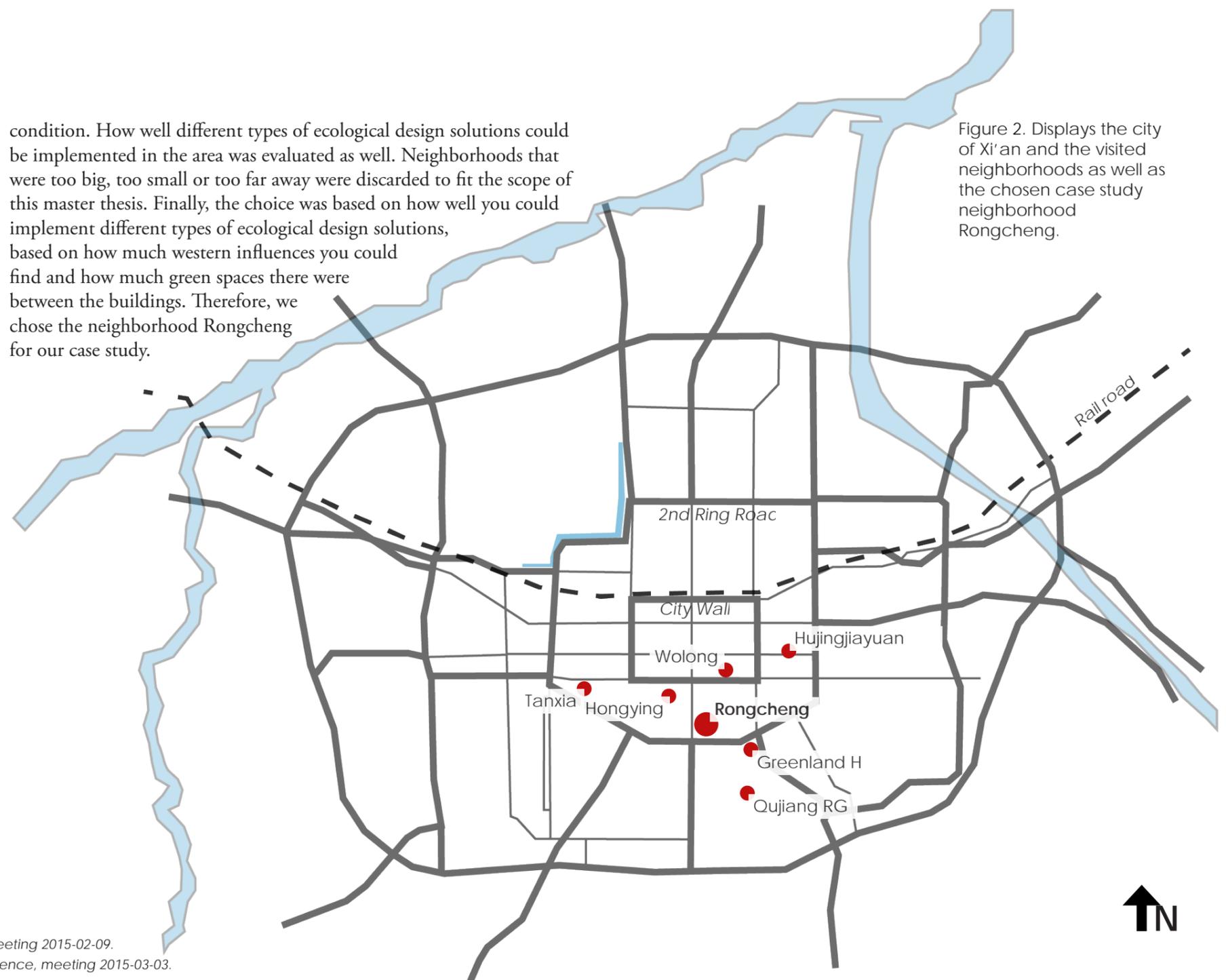
Rongcheng: A neighborhood in Xi'an was chosen for our case study. Seven different quite newly built neighborhoods were visited to get at picture of what a newly built neighborhood in Xi'an could look like, how people use it and what types of green spaces that exists. The reason why we looked at newly built neighborhoods is because they have much more influence from western urban landscapes, which can be analyzed and evaluated on the sustainability and suggested for improvement. In recent years it was a clear tendency of replacing of "old" neighborhoods of 1980-1990s by newer taller buildings. The planning structure and design of green areas were then very much influenced by western principles (Ignatieva et al. 2015). This is the way neighborhoods are built today which makes this type very common and representative in Xi'an (Xiu²).

The visited neighborhoods were Wolong unit, Hongying Garden, Park Tianxia, Rongcheng, Greenland Haipoziting, Hujingjiayuan and Qujiang Royal Garden. The criteria was to find representative neighborhoods of Xi'an that was within a convenient distance from the city center. The seven sites were a recommendation from Ms. Yang³ who is familiar with the city. Pictures were taken inside every neighborhood and a few observations written down, such as the size of the unit, building structure, what elements you could find, social activities, condition of plant material, noise etc.

After visiting all of the neighborhoods, both positive and negative aspects about every neighborhood were written down; for example green infrastructure, microclimate, building structures and general

condition. How well different types of ecological design solutions could be implemented in the area was evaluated as well. Neighborhoods that were too big, too small or too far away were discarded to fit the scope of this master thesis. Finally, the choice was based on how well you could implement different types of ecological design solutions, based on how much western influences you could find and how much green spaces there were between the buildings. Therefore, we chose the neighborhood Rongcheng for our case study.

Figure 2. Displays the city of Xi'an and the visited neighborhoods as well as the chosen case study neighborhood Rongcheng.



The neighborhood has much potential for developing the green structure in a more sustainable manner. It has a lot of water features that could be redesigned for storm water devices, grass dominated lawns that could be transformed into more sustainable ground covers, hard paving that could be turned into more permeable surfaces, compacted soils with bare ground where native groundcover can grow and so on. There are also places for social activities in the neighborhood, which could be interesting bases for the observational study.

Observational study

The work in Xi'an proceeded with an observational study of the chosen neighborhood, Rongcheng. Environmental conditions were observed and recorded in detail such as weather, micro climate, sounds, smells, pedestrian and vehicle circulation, building character, green space character, plant conditions, people's activities etc. See appendix 1 for the designed observation guide. The observational guide for people's activities were designed according to Gehl (2010, pp. 11-15) and we chose different types of necessary activities (e.g. walking, cycling etc.), optional activities (e.g. sitting, reading, exercising etc.) and social activities (e.g. dancing, talking etc.) that we had observed earlier when visited all the other neighborhoods. Gender and approximate age of people were also recorded.

Six observational studies were made, both in weekdays and weekends as well as mornings, afternoons and evenings. Because of constant circulation of people in the neighborhood, we could limit the observation time to 20 minutes and still get a wide picture of how people use the area. Three different locations were set in the neighborhood for the observation, to see if the activities or micro climate conditions varied within the area. The three different sites were chosen to cover most of the neighborhood area. The study was followed by photographing each occasion. We experienced different types of weather during the observational study; sunny, cloudy and rainy.

Table 2. Displays when the observational studies were made and under what weather conditions.

| Date | Time | Weather |
|----------|-----------|--------------|
| Mon 23/3 | Afternoon | Rainy |
| Sat 28/3 | Morning | Sunny |
| Sat 28/3 | Afternoon | Sunny/cloudy |
| Mon 30/3 | Morning | Sunny |
| Mon 30/3 | Afternoon | Sunny/cloudy |
| Tue 31/3 | Evening | Cloudy |



Interviews

During the field study five interviews regarding green infrastructure and ecological design took place with different professors, researchers, a city gardener, a politician and people working with urban planning and green infrastructure. The chosen method was qualitative semi-structured interviews because it gave the persons interviewed a chance to answer the questions in detail and also bring up what they thought was the most important (Bryman 2008). The interviews were made in person. In some cases it was necessary to bring an interpreter. Before the interviews we designed three different questionnaires. One for professors, one for city gardeners and one for local politicians. See questionnaires and the answers in Appendix 2 and 3. The questions concerned different issues of green infrastructure in Xi'an, visions, existing conditions and opportunities of implementing different types of ecological design solutions.

These persons were chosen for the interviews to get opinions and knowledge from local people familiar with the subject and the circumstances in the specific area; Xi'an, China. To interview both higher directing positions and work practitioners gave a broader understanding of the needs in the city and became a significant source and reference to this thesis. The interviews are presented as a summary in the results.

Three different professors and researchers were interviewed:

Doctor QIU Ling. Dr Qiu works at Northwest A&F University as a landscape architecture planner. She has two doctor degrees, one in landscape ecology at Northwest A&F University and one at Swedish University of Agriculture Science in Alnarp. The second is in landscape planning and interdisciplinary methodology development of linking biodiversity in urban green spaces. Totally she has been working in the industry for ten years.

Professor LI Houhua. As a professor at Northwest A&F University in Yangling, professor Li has experienced many years of research in green infrastructure. His main focus nowadays is metabolic engineering of flavonoid biosynthesis in apple by genetic transformation from maize. The genetic research is still going on since 2004.

Professor JI Wenli. Professor Ji also works at the Northwest A&F University in Yangling. Her major subject is to studying flowers, particularly peonies, but she also does researches about forest plants in the urban environment. These two studies have been going on for two respective three years.

One city gardener:

Mr. YU Kanhua. Mr. Yu works in Xi'an, both as a city gardener and as an urban planner. He has worked in this position for fifteen years. The work includes project planning from the city scale to the local scale. He



is therefore both into practice, design and construction of green space.

One local politician:

Mr ZHOU Bin. Mr Zhou works as a local politician in Xi'an. His responsibilities include the green structure in the city planning and the design and maintenance of it as well.

Analysis

The inventory and observational study was followed by the analysis phase. SWOT-analysis and Lynch-analysis were applied on both the big scale and the intermediate scale approach. Below is an introduction of the analysis and why they are convenient in this case study.

SWOT-analysis: intended to identify and list Strengths, Weaknesses, Opportunities and Threats. When the strengths are defined, they can be used to find opportunities. And by detecting weaknesses, it is easier to spot threats (Boverkett 2006). The result is commonly presented in table form.

In the big scale approach the SWOT-analysis was a tool to analyze and evaluate the different types of green spaces that were gained from the inventory, and also to see how they could be developed. In the intermediate scale approach SWOT was mainly used to analyze the green structure in the neighborhood to find out how it could be improved in a more sustainable manner.

Lynch analysis: is a method used to gain an understanding of the image or visual form of a city or a site. The method aims to identify nodes, landmarks, paths, edges, districts and barriers in the city. (Lynch 1960). To fit our purpose, this method were modified to be more applicable to local Chinese conditions. Edges are not included, only barriers, which are typical for Chinese neighborhoods and the only

aspect needed in this case to identify something that blocks the way or counteract passing through. Lynch (1960) defines the aspects as follow: *Nodes:* Strategic spots in the city which are the intensive foci. It could be an intersection or junction, or simply concentrations where people hangout, such as an intensively used square.

Landmarks: A type of point-reference which makes it easier to orientate in the city or a site. They are usually physical objects and could be both distant and local ones, such as a significant tower or a rare bench.

Paths: Channels along which people customarily, occasionally or potentially moves. They may be roads, walkways, bike paths, avenues etc.

Districts: Areas which are recognizable as having the same character. The observer mentally enters inside the areas.

Barriers: Elements which are more or less impenetrable, thus closing one region from another. They can be walls, linear breaks, railroads etc.

In the big scale approach the Lynch-analysis was implemented on the whole city to get a better understanding of the image of the city, for example, defining nodes and landmarks in the city to see where people like to stay and study if the grey infrastructure is contributing or counteracting to the green infrastructure. As for the intermediate scale, Lynch-analysis was a tool to get a better understanding of the specific neighborhood, for example, to see how people move in the area by defining paths in the neighborhood.

Field trip to Shanghai, Suzhou and Beijing

Several places were visited with the aim to gather inspiration for ecological design and the site specific proposal, but also to learn more about traditional classic Chinese gardens as an understanding of Chinese genius loci.

Table 3. Presents the different site visits during the field trip.

| Site visits | Project | Designer | Description |
|-------------|----------------------------|-------------|--|
| Xi'an | Sponge Park | Kongjian Yu | A demonstration park for ecological design solutions. It is only the first stage of four in the project that is finished at the moment. It will be a green corridor with flood control and purification of the water. |
| Xi'an | Feng Xi local municipality | Turenscape | A housing estate where the design is focused on the ecological perspective. The storm water is collected in sustainable storm water managements, such as rain gardens. |
| Shanghai | Houtan Park | Kongjian Yu | An ecological park built on a former industrial area on the riverfront of Huangpu. The park treats the polluted water from the river and includes ecological flood control, constructed wetland, urban agriculture and reclaimed industrial materials. |

| Site visits | Project | Designer | Description |
|-------------|--|----------------------|--|
| Shanghai | World Expo Park | Unknown | World exhibition park. The purified water from Houtan Park is collected in this park where it is used as irrigation water. |
| Suzhou | Lingering Garden Humble Administrator's Garden Lion Grove Garden | Old masters | Classical Chinese gardens where the design is in typical Chinese style. They seek to depict the natural landscape in miniature. |
| Beijing | Temple of Heaven | Emperor Jiajing | The symbolic layout and design of the park had a profound influence on the planning and architecture in the eastern world for many centuries. |
| Beijing | Summer Palace | Emperor Wányán Liáng | An imperial park where the natural landscape (hills and open water) is combined with artificial features typical for China (temples, palaces, pavilions, bridges etc.). |
| Beijing | Forbidden city gardens | Emperor Yongle | Forbidden City was the Chinese imperial palace. It consists of several enclosed yards of different sizes. The palace complex is an example of traditional Chinese palatial architecture. |

Photo documentation

Approximately 20 000 photos were taken within these eight weeks for memory support, inventory and inspiration. Most of the photos taken served as support for the observational study and inventory of the neighborhood. But there were a lot of photos taken of different types of green infrastructure, different imperial gardens and public parks in China as well. All photos in this thesis are property of the authors unless otherwise stated.

Producing plans and visualizations

Gathered information from inventories, observational studies, analysis and the result are processed and presented in visualizations and plans. All visualizations, cross sections, perspective drawings and plans in this project are made by the authors in Adobe Illustrator and Photoshop.

Sponge park - Xi'an



World expo park - Shanghai



Temple of Heaven - Beijing



Feng Xi rain garden - Xi'an



Lingering Garden - Suzhou



Summer palace - Beijing



Houtan park - Shanghai



Lion Grove Garden - Suzhou



Forbidden city - Beijing



An aerial photograph of a cityscape. In the background, several tall, modern high-rise apartment buildings with beige facades and blue-tinted windows stand against a hazy sky. One of the buildings has the Chinese characters '中海御湖1号' (Zhonghai Yuhu No. 1) visible on its upper floors. In the middle ground, there is a dense cluster of lower-rise residential buildings with red-tiled roofs and light-colored walls. In the foreground, a lush green park area is visible, featuring a dense canopy of trees and a modern, elevated pedestrian walkway or light rail track supported by red pillars. The overall scene illustrates the integration of green infrastructure within a high-density urban environment.

URBAN GREEN INFRASTRUCTURE

This chapter illuminates why green infrastructure is important in the city and what benefits we gain from it. There is also an introduction to the ecological design concept.

WHY GREEN INFRASTRUCTURE?

The following paragraphs enlighten green infrastructure in the cities, what a green infrastructure plan is, why it is important in the cities and what benefits they provide.

Green infrastructure

The term green infrastructure is appearing more and more frequently across the world. Green infrastructure, however, can mean different things depending on the context in which it is used. The definition of green infrastructure in this thesis can be found in the chapter Definition and abbreviations. It says, in short terms, that green infrastructure includes all the vegetation areas in the cities and in their surroundings. For example it could be parks, gardens, parkways, cemeteries, lawns, roadsides, railway wedges and riversides (Ignatieva & Ahrné 2013). Benedict & McMahon have another definition:

We define it [green infrastructure] as an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife. Used in this context, green infrastructure is the ecological framework for environmental, social, and economic health – in short, our natural life-support system. (Benedict & McMahon 2006, p. 1)

It is thus not just a system of greenways; green infrastructure provide significant ecosystem services and have a positive impact on biodiversity, environmental conditions, economy and social values, such as health aspects (Ignatieva & Ahrné 2013). Benedict and McMahon also mean that green infrastructure highlights the importance of open and green space protection and management and further state the difference between green space and green infrastructure. "...green space is often viewed as something that is nice to have, green infrastructure implies something that we must have." (Benedict & McMahon 2006,

p. 2) In practice, this means that protecting and restoring of green infrastructure is essential, not an amenity.

The term green infrastructure is new, but not its concept. It has its origin in two fundamental initiatives (Benedict & McMahon 2006, p. 16): (1) protecting and linking parks and other green spaces for the benefit of people (recreation, health, aesthetics and urban design) and (2) preserving and linking natural areas to benefit biodiversity and counter habitat fragmentation (protecting native species, natural processes and ecosystems). According to Müller and Kamada (2010), a better understanding of the interactions between patches, corridors and the urban matrix is required to be able to maintain and improve the ecological networks, which the green infrastructure is a prerequisite for. Because of the densification of cities there is also a need to consider other dimensions of green such as green walls and green roofs in addition to conventional green infrastructure on the ground level (Ignatieva & Ahrné 2013).

Green infrastructure plan

With the ongoing urbanization in the latter part of 1960s, vegetation in urban areas began to be seen as a coherent pattern (Boverket 2012). Green spaces in cities are linked independently of administrative boundaries and forms a whole - a green infrastructure (Boverket 1994). Further refers that green infrastructure planning must be planned with great knowledge to achieve a sustainable urban development. Green structure has weak protection or in many cases no protection at all (Bucht & Persson 1994). Today's densification of cities has become a threat to the green structure and over the past twenty years there is a great loss and fragmentation of green spaces in cities, according to Bucht & Persson (1994). The smaller and more scattered parts of green areas have inferior use for humans as well as for plants and animals survival (Boverket 1994). Further mentions that it also has implications for local storm water management, air quality and local climate. The



connection between the city's greenery and hinterland is crucial to maintain functioning ecosystems and requires green links between the city and the landscape (Boverket 1994).

A green infrastructure plan can thereby be used as a tool in planning processes to protect and develop green areas in cities. A green infrastructure plan is not legally binding but it is supposed to guide urban and spatial planning and can serve as a basis in master and detail planning (Malmö Stad 2003). The green infrastructure plan can be based on either a vision or a goal but regardless of what, it is important to define why a green structure plan should be made (Boverket 1994). It is possible to implement the green infrastructure approach at any scale (Benedict & McMahon 2006). At the community level, according to Benedict and McMahon (2006) it could involve creating greenways to connect existing public parks to one another. Furthermore at the regional level it could mean protecting wide-ranging landscape linkages that combine forests or other natural areas and serve as a habitat for animals.

Benedict and McMahon (2006) pointed out that, when creating a green infrastructure plan or network you have to look for where opportunities exist. There may be obvious in some areas finding lands of conservation value that could serve as linkages. On the other hand, they mean that green infrastructure network may have to rely on lands reserved for other uses such as military installations, riparian lands, lands used for agriculture, forestry, parks, golf courses, railroad corridors, brownfields etc. Designing a green infrastructure plan or network can support the community to protect its most ecologically valuable land while leading developments toward areas more suitable for human use (Benedict & McMahon 2006).

BENEFITS FROM GREEN INFRASTRUCTURE

Green infrastructure in cities has a number of adequate functions from both ecological, social and cultural point of view (Bucht & Persson 1994): prerequisite for biodiversity, ecosystem services, habitat for flora and fauna, better microclimate conditions, positive impact on air quality, storm water drain, enrich the living environment, bearers of cultural values, places for recreation and outdoor activities, better understanding of the natural cycle and positive impact on health aspects. According to Professor Li (interview 2015) the biodiversity in Xi'an is poor and the air quality is even worse.

Urban Biodiversity

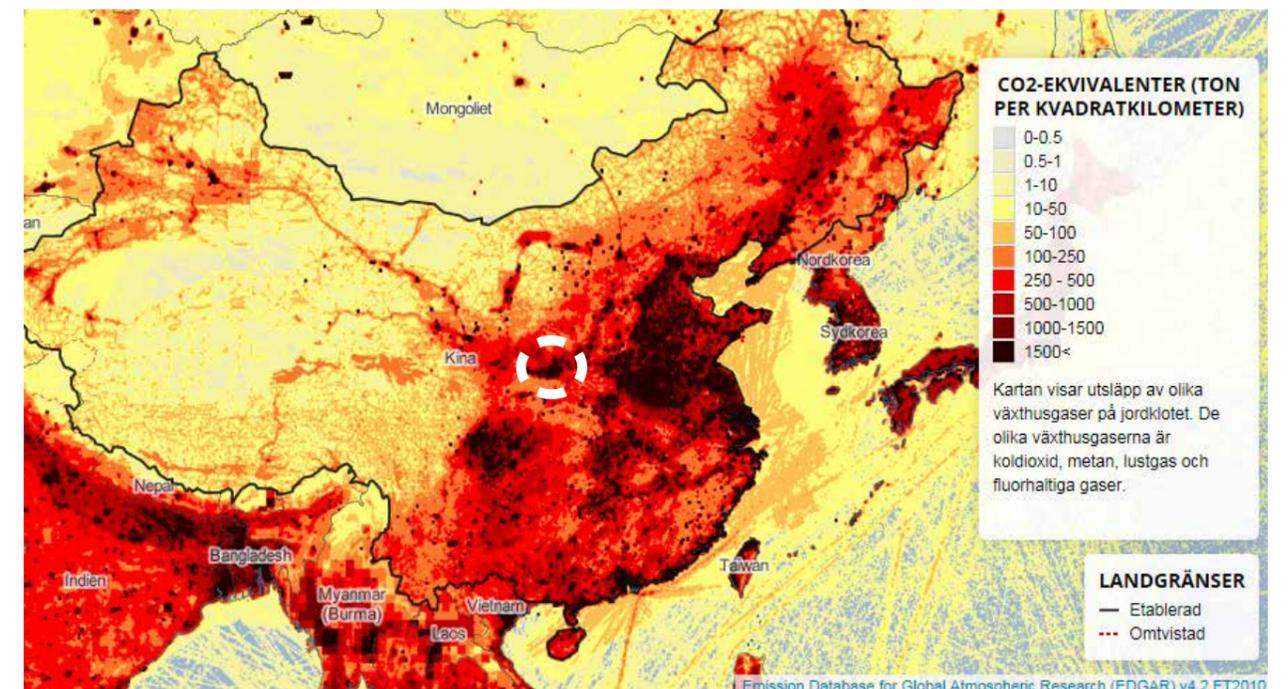
Today there is an increasing variety of animals and plants threatened by extinction, both regional and global (Boverket 1994). It is important to retain biodiversity, because it is not only providing ecosystems and species, it also provides us with a wide range of food, medicine and shelter (Benedict & McMahon 2006). Furthermore, according to Benedict and McMahon (2006), when biodiversity is involved in network design goals and infrastructure planning, it gives policymakers and land-use planners' adequate information to make decisions that will minimize the impact of development on habitat. Therefore, as stated by above, green infrastructure takes biodiversity protection a step further. Interconnected green corridors provide an opportunity for animals and plants to spread between fragmented parts of green areas (Bramryd & Fransman 1993).

Another important quality is that biodiversity, while maintaining its core function and character, increases the resilience of ecosystems to respond and adapt to change (Rottle 2010). Numerous of benefits are provided when the biodiversity is maintained in urban environments. The impact on human health and wellbeing is affected depending on the biodiversity in the cities (N. Muller, P. Werner & J.G. Kelcey 2010).

Humans have lived in close proximity to the nature for most of its evolution and existence which means it plays a significant role for the human life on earth. The human species are part of an ecosystem and all kinds of species in the system are important for the function, they are independent (Rottle 2010). But due to the increasing population in the cities, considering urban biodiversity is urgent (Muller 2010).

A city is also included in larger ecosystems with the processes and species they support (Muller 2010). Therefore, to determine the health and biodiversity of wider ecological systems urban areas often play an important role. It can work as stepping stones for many species during different seasons and the citizens and the local ecosystems benefit from the ancient interactions with these species (Rottle 2010).

Figure 3. Map of greenhouse gas emissions in China. Xi'an is marked with a dashed circle. The city emits more than 1500 tons of greenhouse gases per km². --> Source: Globalis 2015.



Climate and air quality

Carbon dioxide is a vital gas and part of the ecosystem (Globalis 2015). This gas has increased in the atmosphere because of the anthropogenic emissions; it reinforces the greenhouse effect which leads to climate changes on earth. Emissions of carbon dioxide are there for a substance which is desirable to reduce. China emits the most carbon dioxide in the world and it is 33 percent more than the United States which is the second country to emit large quantities of carbon dioxide (Globalis 2015). See figure 3.

Green areas play therefore an increasingly important role as a climate regulator and a filter for the air pollution in urban areas (Statens



folkhälsöinstitut 2009). It becomes more and more important to increase the stand of trees in the cities, especially in cities with high contamination levels (Bramryd & Fransman 1993). Different type of vegetation can mitigate pollution with different efficiency. For example trees purify the air more efficiently than lawns (Boverket 1994). Möllersten (2001) explains that contaminants from the air accumulate on the leaves and needles and rinse to the surface with rainwater. Another way of how plants purify air is by absorbing gaseous substances through their stomata (Bramryd & Fransman 1993). Further means that from a health perspective, it is important to reduce both the dust particles as well as the gaseous pollutants.

In particular conifers have a significantly better ability to filter dust and pollutions from the air, the reasons are because they keep the needles all year round (Möllersten 2001) and they have the greatest relative surface exposed to the air (Statens folkhälsöinstitut 2009). Purification ability of an acre deciduous forest is estimated to fifteen tons per year, according to Möllersten (2001), and for conifers the estimated level is two to three times bigger. The deciduous trees though, are less sensitive to air pollution and better at absorbing gases (Statens folkhälsöinstitut 2009). According to the German scientist Aloys Bernatzky parks can absorb 80 percent of air pollutants and street trees up to 70 percent (Boverket 1994). For the most optimally function the vegetation in the city, primarily trees and shrubs, should consist of both conifers and deciduous (Statens folkhälsöinstitut 2009). There for, high wide trees combined with a dense shrub layer can be used to improve the air quality around roads with heavy traffic (Bramryd & Fransman 1993). The vegetation is the lung in the city (Statens folkhälsöinstitut 2009).

In urban environments the temperature is often measured higher than in the surrounding areas due to the heat absorbed in buildings and streets in the cities (Boverket 1994). This phenomenon is called “urban heat islands”. Natural ecosystems with vegetation and water reduce

these effects by evaporation and make the temperature differences more even. Urban green spaces can reduce the temperature at heating periods significantly (Statens folkhälsöinstitut 2009). Vegetation is thus of great importance for a city like Xi’an with an air temperature of forty degrees Celsius during the summer. Air temperature increases acutely when the vegetation represents less than 25-30 percent of the city area (Boverket 1994). The vegetation can also contribute to a cooling effect by providing shade in the city (Statens folkhälsöinstitut 2009). Vegetation also absorbs strong winds and thereby generates better microclimate conditions on the local site (Boverket 1994). Furthermore declares that especially big trees have great impact on the wind.

Health aspects

Research has shown that nature can mitigate stress and that people’s ability to concentrate is strengthened when being in nature (Boverket 1994). Further refers that hospital studies in Sweden shows a reduced need for drugs, painkillers and sleeping pills when patients had access to green areas.

Nature has an essential importance for both the physical and the psychical health. Physical activities are promoted when green spaces are close by and the physical aspect is affected just by staying in the nature (Statens folkhälsöinstitut 2009). A study at a hospital in Pennsylvania, USA, also showed that only by having a view of a park from the window accelerated the healing process (Möllersten 2001). Even to have houseplants have a positive impact on the health. To have houseplants in the office can make people feel less stressed and be more creative (Statens folkhälsöinstitut 2009).

A theory about nature’s healing properties is that humans absorb the outside world in two ways; with targeted and spontaneous attention, according to Statens folkhälsöinstitut (2009). The targeted attention means that people focus on what’s important, their main tasks, and

sort out all other impressions. It is used in daily life when remembering things, plan and take decisions and it demands great concentration and cost a lot of energy. Therefore it has to be a possibility to disconnect the targeted attention so it doesn’t lead to mental exhaustion. The best way to avoid it is in a situation where a lot of unintentional or spontaneous attentions are used. Further describes that natural environment has proven to be very effective in this regard. The impressions of rustling trees and bubbling brooks are “soft” impressions and encourage spontaneous attention which requires no effort. To stay in nature thus, implies that the body is able to recover mentally and relax from all the targeted impressions that exist around us (Statens folkhälsöinstitut 2009).

Ecosystem services of GI

- **Better air quality**
- **Climate regulator**
 - Better microclimate conditions
- **Storm water drain**
- **Urban biodiversity**
- **Pollination**
- **Food resources**
- **Recreation values**
 - Aesthetic
 - Cultural
- **Shelter**
- **Positive impact on health**

What is Ecological Design?

Ecological design could have two definitions, as a verb and a noun. As Rottle (2010) define it the verb:

“embodies a series of actions that include the initiation of design concepts aimed at improving environmental health, developing those concepts into plans based upon the particular qualities and processes of places, and the implementation of detailed plans while responding to the dynamics of change over time.”

Ecological design as a noun, as Rottle (2010) describes it;

“exist in the form of healthy, regenerative systems and components of our built environment. From parks and preserves, to buildings and streets, an ecological approach to design can be integrated into the fabric of our communities, serving as a new kind of infrastructure.”

Van Der Ryn & Cowen (1996) have another definition of ecological design: *“any form of design that minimizes environmentally destructive impacts by integrating itself with the living processes”*.

The aim of ecological design though, is to improve ecological functioning, enhance species diversity, minimize resource depletion, maintain and create resources for human use, and encourage a more resistant method to the design and management of the built environments (Van Der Ryn & Cowen 1996). Ecological design, as an interactive approach and process, includes both human and non-human systems and communities and to create a sustained, resistant environmental quality the best scientific theory and evidence has to be applied (Rottle 2010). Hence, according to Van Der Ryn & Cowen (1996), it requires adaption to and integration with nature's processes.

The form and function of different kind of ecological designs have to be adapted to the specific area, but there are some guidelines provided in theories about the ecological landscape, according to Rottle (2010). How to maintain and improve the integrity and diversity of a region's ecological relationships are examples of that. The designer has to take the flow of organisms and nutrients into account to understand and address these relationships in the design (Van Der Ryn & Cowen 1996). The design aims to mimic or replicate the natural systems cyclical patterns, which support a sustainable development and regeneration over time (Rottle 2010). Designing with nature in urban context can also lower the amount of maintenance thanks to stable plant dynamics that occur when plants coexist. The best way to achieve this is with native species (Dunnette & Hitchmough 2004).

Cyclical flow of energy is promoted in ecological design and what is sought is a self-renewing and regenerative system (Van Der Ryn & Cowen 1996). The aim is to increase biodiversity, the design to become resilient and improve the health of all communities, human as non-human, by protect and build upon the structures and processes which enable that (Rottle 2010).

To reduce human impacts on the planet, applying principles of ecological design and planning in the cities, is one solution, Van Der Ryn & Cowen (1996) states. Cities are not just a big source of emissions; they are also one of the solutions of the crisis of the global environment. A balance of density and amenities in urban areas gives the inhabitants a high quality of life while carbon dioxide emissions and the fossil fuel consumption can be reduced (Rottle 2010).

According to Van Der Ryn & Cowen (1996), ecological design has become increasingly more important than before and with even greater considerations. Increasing evidence of climate change caused by man has stimulated global awareness and concern about future impacts

on vulnerable people, sensitive species and the decreasing quality of environmental conditions worldwide. To use ecological design in the urban environment, it could thereby help mitigate and adapt to these changes. The cities will be more livable and ecologically resilient and at the same time each person's ecological impact will be reduced (Rottle 2010).

Practical application of ecological design

The use of ecological design you can find all over the world, in greater or lesser extent. According to Dr. Ling (2015), implementation of ecological design in public green spaces would definitely be necessary, it is also a smart way to develop the urban greenery. Here are examples of some projects focusing on urban ecological design.

Red Ribbon Park – Qinhuangdao, Hebei, China

The Red Ribbon Park is a 500 meter long park at the riverside of



Tanghe River. Before it became a park it was an unkempt area, the place was a garbage dump, with deserted houses. In the restoration of this area they wanted to preserve as much as possible of the natural environment, it is a minimalistic design engagement but it creates a dramatic melioration of the scenery. Ecological processes are maintained while the lighting, seating and the boardwalk tailor the need of the local residents (Saunders 2012).

The High Line - New York, USA

The High Line Park in Manhattan is a 2,33 kilometer long park in New York. The park is built on a former freight railway which is elevated above the ground. This project is an example of integrating greenery in the city. It increases the biodiversity and creates new pathways for plants, insects and people (La Farge & Darke 2014).

Cheong Gye Cheon Stream - Seoul, South Korea

A restoration of a culturally and historically important stream corridor in Seoul. The main reason for restoration was serious sanitary and flooding problems. After restoration was completed in 2005, fresh water runs through the area and supports terrestrial and aquatic habitat in the central part of the city, mimicking landscape forms and integrates open spaces (Seoul Metropolitan Government 2011).

Augustenborg – Malmö, Sweden

The eco city Augustenborg was restored to be a more social, economic and ecological sustainable neighborhood (Malmö stad). The proportion of green areas were increased and enriched, and the biodiversity was also a goal in this project. There are plenty of green roofs which contribute a lot to the biodiversity by attracting birds and insects. Biologists estimate that the green roofs increased the biodiversity in the area by fifty percent. The project has also focused on energy efficiency, sustainable storm water management and in renewable energy (Malmö stad 2015).



DESIGN WITH ECOLOGICAL PROCESSES

Alternative biodiverse lawn - Ultuna, Uppsala, LAWN Project
Demonstration Trail of alternative lawns



Low Impact Design

Low Impact Design, LID, is a method to manage urban storm water in an environmental sensitive approach (Ignatieva et al. 2008). It requires designing and working with nature in an alternative, cost-effective way for the urban development. Another similar concept is Ecological Storm water Management, ESM (Bashkirov et al. 2015). Both create community environments that respect, preserve and improve the natural processes according to Ignatieva et al. (2008). Further follows examples of LID.

Rain gardens

A rain garden is a permeable plant bed which purpose is to delay, infiltrate and clean storm water from nearby paved surfaces (Veg Tech 2015). According to Veg Tech (2015) the system with infiltration beds, rain gardens, were developed in the United States and Canada where they found out that several small storm water facilities were more effective than a few large ones.

Veg Tech (2015) points out that the rain garden systems were from the beginning a phenomenon of mainly smaller real estates and private gardens. Now a day they are used with success even in the urban environment, such as street environments. The storm water from roofs, roads and parking areas is headed to the nearby rain gardens where the plants purify and evaporate large parts of the water before it infiltrate trough the plant bed. No excess water need to be passed on to the conventional storm water system, all of it infiltrates locally and creates a closed storm water system within the area (Veg Tech 2015).

Bio swales

Bioswale is a general term for vegetated swales, ditches and other depressions that carry storm water (Ignatieva et al. 2008). There are two basic types of bioswales, the open channel bioswale and the fully vegetated bioswale, the difference is the degree of vegetation. Jurries

(2003) explains that these types can be further more divided into subtypes which are based on the cross sectional shapes; the “V”, “U” or “trapezoid” shape. The bioswale that is most effective to remove pollutants is the fully vegetated trapezoidal bioswale. The V and U types are often normal ditches that are open channeled and have become naturally vegetated. They do not contribute to the combating process of pollutants more than the infiltration of storm water (Jurries 2003). An important criterion when choosing plant material is the ability to enhance soil and water quality by filtration (Ignatieva et al. 2008).

Bioswales are designed to manage a certain amount of water so they can handle storm event like the two year 24-hour storm events, as an example. But according to Jurries (2003) the amount of water in the storm events are less than the design amount in 90 percent of cases. In bioswales the retention time of the storm water plays a significant role, Jurries (2003) means; the longer the water stays in the bioswales the more effective the removal efficiency. Also the vegetation types and its life cycle are important for the pollutant removal rate.

Green roofs

Green roof is a generic term for different roof solutions which includes organic material (Byggros 2015). It can have different designs, from just a simple sedum mat covering the roof to a garden or a landscape roof rich in species. These roofs recreate a natural ecosystem where the buildings have been placed; it also cleans the air and decreases the temperature in the city (Svenska naturtak 2015). It is estimated that an area of 10 m² covered whit drought tolerant vegetation on a roof absorb as much carbon dioxide as a grown tree (Miljönytta 2015). Green roofs are likewise a way to increase the biodiversity in the city (Veg Tech 2015). However, the most common function of modern green roofs today is regulation of runoff (Ignatieva & Ahrné 2013). According to Svenska naturtak (2015) they absorb 99% of

the precipitation and evaporate almost all of the water depending on climate and season.

Vertical gardens (green walls)

A vertical garden is another way to incorporate greenery in urban environments (Svenska naturtak 2015). It is a facade mounted system where plants grow, with or without its' roots in soil. Svenska naturtak (2015) mentions many good qualities, for example improving the urban climate and environment, decreases the strong heat and smog in the city, filtering harmful substances, it has a cooling effect in the summer and an insulating effect in the winter inside the buildings, it increase the biodiversity of species in the city, intercepts and absorb carbon dioxide and produces more oxygen.

Alternative biodiverse lawns

An alternative biodiverse lawn is an alternative to conventional lawns which can be more durable, embossed by biodiversity and at the same time useful and aesthetically attractive (Biodiverse 2015). The seeds are a mixture of only natural sources and collected only from native plant communities. These biodiverse lawns will look different depending on what part of the world they are and because of the choice of native seeds, according to Biodiverse (2015). Different flowering species makes the biodiverse lawns, as stated above, very beneficial for the biodiversity (Ignatieva & Ahrné 2013). The idea is also to let the lawn thrive without regularly mowing and by that contribute to a sustainable green environment with less air pollution.





SITE DESCRIPTION

This chapter gives an introduction to China, Chinese culture, classical Chinese gardens and symbolism as well as an introduction to Xi'an and its history and environmental conditions.

China was for a long time, and still is to a certain extent, a bureaucratized agricultural society. This has left its' marks on the cities of China. The ruling imperial city administration was financed substantially of taxes on agriculture which has meant that Chinese cities have had a weak position formally in the Chinese history. But the cities matter grew and in conjunction with the "commercial revolution" during the Song Dynasty (960-1280), the first wave of urbanization in China took place (Cassel 2008).

Now a day there is an unimaginable fast urbanization in China and with that comes many risks, for example deterioration of the environment because of the strains on natural and cultural environment, increased pollutions and climate risks from the heavy process industry and the rapid increase in fossil fuel (Cassel 2008).

Environmental conditions

China is a country situated to the east of the Asian continent and is showing both maritime and continental topography (Jin 2008). The topography consists of mountains, plateaus, plains, basins, lakes and hills. According to Jin (2008) the climate is very diverse combining temperate, warm and subtropical zones with a generally mild range of temperature and four distinct seasons. The major part of China lies at a degree of latitude to the south of Europe. Thus, during summer months, the southwest wind leads to higher temperatures than are experienced in other countries at the same latitude and on the other hand, due to the north wind, the climate is both drier and colder in winter compared to other part of the world at similar latitudes (Jin 2008). Most precipitation falls during summer, although regional variations due to the topographical features exhibit. As stated by Jin (2008) there is a long rainy season in the south from May to October and in the north a shorter one from July to August.

Urban green space planning

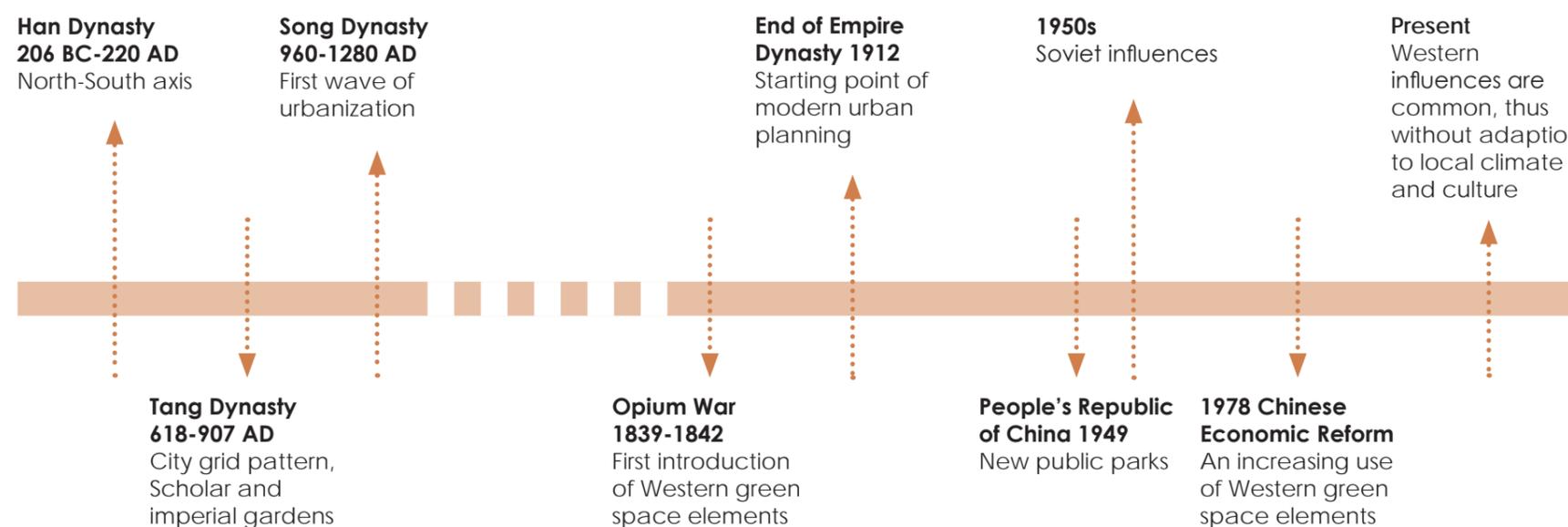
For more than 2000 years, the most dominant type of green space in Chinese cities were classical Chinese private gardens (such as scholar and imperial gardens) and different scenic spots (chosen for their beautiful natural landscapes) (Ignatieva et al. 2015). These gardens were constructed according to harmony and beauty of the philosophy of Taoism, Confucianism and Buddhism.

The first public park in China was built in 1868 by the time China partly became a Western colony (Chen 2013). Foreign missionaries in the First Opium War (1839-1842), were the first ones to introduce European element of green spaces though, such as lawns and flowerbeds to China, states Ignatieva et al. (2015). With the establishment of the People's Republic of China in 1949, some offcuts of colonial gardens as

well as imperial gardens, were turned into public parks (Chen 2013). In the 1950s, public parks adapted the "Learning from the Soviet" policy, meaning that multifunctional parks of recreation substituted private gardens and political and economic campaigns influenced the urban development, Chen (2013) states further. Greenbelts and green infrastructure plans were also enlightened at that time.

With the Chinese Economic Reform in 1978 came an increasing use of Western green space elements, when governmental officials went abroad and became fond of manicured lawns and colorful flowerbeds. It was also included in the globalization process when China became a member of World Trade Organization, means Ignatieva et al. (2015). Since 1990, the use of global plant material also increased.

Figure 4. Shows a timeline of the Chinese history of green space.



The new Western influences were adjusted neither to the Chinese climatic conditions nor the local cultural conditions though (Ignatieva et al. 2015). Classical Chinese park elements have nowadays lost their spiritual meaning and the costs for maintaining the Western lawns and flowerbeds are rising. And so is the pollution due to the high maintenance.

Chen (2013) states that China's urban landscape has become uncritically Europeanized and Americanized, hence, become a huge experimental field with lots of Western elements, such as huge plazas, large areas of plane lawns and colorful flowerbeds with global species seen almost all over the world. Chen (2013) means further that with the high speed urbanization, came massive suburbs and business districts that encroached the already fragile and fragmented urban natural environments.

Today, design and planning for urban green areas are mostly done by Chinese private architectural/landscape architectural firms and by planning municipal institutions. Ignatieva et al. (2015) also states that in some cases, especially in big-scale projects, foreign consultants and firms also take part in the design and planning process.

The main green areas in Chinese cities these days are public parks, green areas inside living neighborhoods, environment next to educational campuses and governmental institutions, green plazas in the front of administrative buildings and important historical monuments, urban nursery plantations, intensive green roofs, trees and vegetation along the streets and also native forests around the city transformed into public parks (Ignatieva¹). Vegetation along the streets plays an important role in urban environment, but it has a tendency to be monoculture with few species. They have a very standardized design; one tree species in rows is a common view in the Chinese cities (Ignatieva¹).

Today, Chinese cities are facing an increasing densification, traffic problems and air pollution, which have forced the Chinese landscape architects to search for new sustainable models for urban development as well as finding the local identity of a place again (Ignatieva et al. 2015). According to Chen (2013), developed cities like Beijing, Shanghai and Shenzhen have begun practicing ecological planning and design into urban environment.

In recent years, green roofs have become a popular concept in China, in search for more sustainable solutions, but there are not many green roofs yet, according to Ignatieva et al. (2015). Green roofs do provide ecosystem services to the megacities, but so far, the maintenance costs are too high for mass production, she states.



Laws and regulations of green space

In the national urban planning law in China, City and Rural Planning Act (2008), there are no independent "law-level" jurisdictive documents specifically directed at green space issues (Chen 2013). But the urban green space planning is an independent practice with corresponding guidelines. The document Regulations on Urban Greening (1992) illuminates the importance of green areas in urban development and works as the highest level legislative document for urban green space planning, according to Chen (2013).

Regarding laws and regulations for citizens' use of green space in China, lawns are for example prohibited for public use in parks (Ignatieva et al. 2015). Therefore you can find a lot of prohibition signs for not stepping on the lawns in Chinese public parks and some of them are very creative as well. There are also prohibition signs for not breaking the plants. See picture below and on page 29.



People also have limited access to public parks in China. The public parks are gated and only accessible during their specific opening hours. Some of the heritage parks or other very popular public parks also charge a fee to enter.

Laws in China regarding GI

- Regulations on Urban Greening (1992)
- City and Rural Planning Act (2008)

Positive

- + Popular
- + Well maintained

Negative

- Limited access
- Gated
- Entrance fee in some parks

Prohibition sign in Xi'an



Entrance fee required



Alternative prohibition sign in Xi'an



Encouragement to care for the green environment



CLASSICAL CHINESE GARDENS

Classical Chinese gardens have influenced parks and gardens throughout the world (Sirén 1950). The foundation of the Chinese garden design, as well as for urban planning and art, are the Daoist's love of nature and the Confucius's encouragement of self-cultivation (Ignatieva¹). The ancient Chinese gardens “express the humanistic spirit through pursuing the beauty of the natural landscape and are in harmony with the thought ‘a perfect integration of man and nature’.” (Jin 2008 p.122). Paintings and poetic descriptions of nature provide the ideal that underlies Chinese garden design and the primary source of inspiration is nature's own forms (Rogers 2001). Traditional Chinese garden elements are rocks, water bodies, bridges, pavilions, winding corridors and pagodas (Sirén 1948).

A Chinese garden should not seem like a transparent, symmetric construction, at first sight it should be seen as an ideal landscape that attracted walking and captivated with its many motifs, surprisingly vistas and associative allusions (Sirén 1950).

The prime motivator and the starting point of understanding Chinese gardens has been the landscape in both picture and reality (Sirén 1948). Agricultural early affected the landscape (Svalin 2003). New methods were used to operate and improve the nature, to form and beautify the landscape. As time went its appearance slowly changed. The knowledge from the cultivation was useful even in the gardens. The way soil was moved to create better growing beds, ditches and terraces in the landscape gave ideas of how to design the gardens; digging out lakes and building up mountains. According to Svalin (2003) there was a longing to get the unspoiled countryside into the gardens, but it was too comprised to fit. There for, only the most important parts were recreated and it was up to each individual to interpret and determine what parts. Details like watercourses and mountains were recurred repeatedly. Sirén (1948) also points out that a Chinese garden without buildings is not a Chinese garden, they complete the composition.

In Chinese gardens, rocks have a strong aesthetic and associative value, as the mineral substance of nature (Rogers 2001). The rocks usually intend to mimic the mist-shrouded mountains of the larger landscape and as a viewer you are supposed to be encouraged to enjoy the abstract beauty of these spatially intricate rocks and paradisiacal iconography. The combination of mountains, shan, and water, shui, means landscape, Rogers (2001) explains. Mountains are further associated with immortality. The rocks in Chinese gardens should be animated by *qi*, the invisible energy source and pulsating breath, so that they become presences alive to eye, hand and mind (Rogers 2001). Manuals have been written for the selection of stones, but “there is no definite way of making scenery; you know when it is right when it stirs your emotions” (Rogers 2001, p. 287). Inscriptions onto rocks and stones are also common, according to Rogers (2001).

Scenic spot, Zhangjiajie national park



Classical Chinese Gardens

| Private Scholar | Imperial Gardens | Scenic Spots |
|-------------------|--------------------------------|--------------------------|
| Gardens of Suzhou | Daming Palace Summer Palace | Zhangjiajie mountains |

Chinese gardens can be divided into two categories: the royal imperial garden and the private garden (Jin 2008). In Qing Dynasty several royal gardens were constructed in the west of Beijing. The largest one was Yuanmingyuan, which aimed to take in all the beautiful sceneries under the heaven. Private gardens date back to Han Dynasty. Jin (2008) explains that private gardens were built by rich merchants, celebrities and gentries. A great number of private gardens were built in Suzhou and once there were as many as 270 private gardens there at the same time. Suzhou has therefore got a reputation for being the garden mecca (Rogers 2001).

In Chinese gardens, walls are an important element that segregate space and make the garden invisible to passersby, except from glimpses through latticed openings (Rogers 2001). Further mentions that the function of a wall is to serve as a background for rocks and plants,

Classical Chinese garden in Suzhou

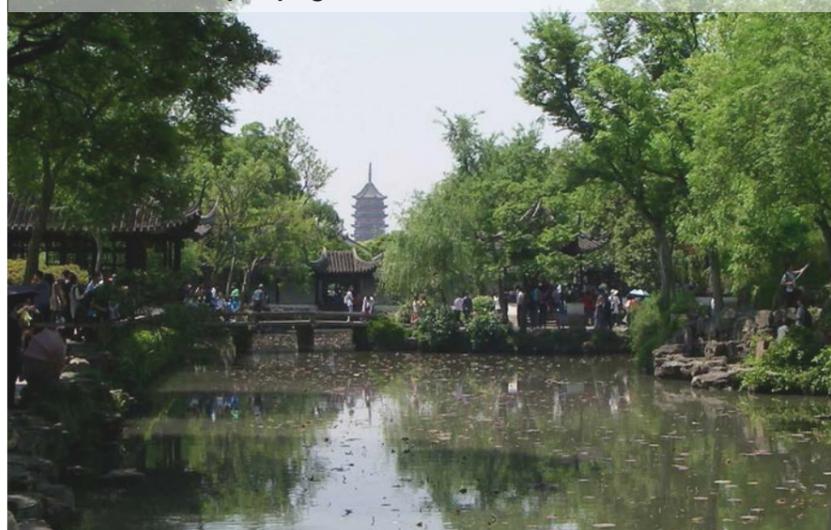


capturing calligraphic patterns from its shadows. Bamboo grove, pines, peonies, flowering plum and peach trees and willow trees are common, according to Rogers (2001).

Borrowed scenery, *jie jing*, is something that is to be found in Chinese gardens and for that requires good siting as a primary ingredient of garden making (Rogers 2001). For example it could be a distant view of misty mountains, a picturesque view of a lake and its surrounding scenery, roof lines of a nearby monastery, or flowers of a neighbor's garden place. Pavilions are also common elements in Chinese gardens and by the Tang Dynasty, they were used, as an established form of entertainment, for literary drinking parties (Rogers 2001).

Confucius, Lao Zi and Buddha are the three philosophes that gave rise to Confucianism, Daoism and Buddhism. These doctrines are fundamental to understand why the gardens look the way they do and what you really see (Svalin 2003).

Borrowed scenery of pagoda



Confucianism

In the Chinese society Confucianism was the ideology that the world was organized by (Svalin 2003). It aimed clear hierarchy and moral rules in attempts to recreate the original harmony and order that once existed in the world. Svalin (2003) declares that Confucianism was strict and the principles should be followed.

The state and the family were the basic units, all relative to each other. Man was a part of cosmos and its actions and expressions were as important as events in nature, they were equally worthy (Svalin 2003). Confucianism formed the basis for the practical chores in the state (Svalin 2003). It was the most scholarly people who could become an official of the state, they were best suitable to lead and refine the society. Those bureaucrats played a big role in the garden history.

Many of the officials had their origin in rural areas (Svalin 2003). In



repeated periods of China's history the officials fell into disfavor with the emperor and got to leave the hoof and the government services. They moved back to the farm and the garden far away from the city to live a simple and rural life with cultivation and gardening beneath flowering trees. They shut the world out and lived an uncomplicated life Svalin (2003) explains. Paint, write poetry, drink wine, grow flowers, play chess and work with calligraphy were common chores and it was the best way to recovery. To cultivate oneself was as important as cultivating the soil, it was one way to improve the human nature (Svalin 2003), and the garden was the place where it should be done, the place where the activities took place most of the year (Sirén 1948).

But too much physical activity was not good, it was important to have time to reflection and spiritual development (Svalin 2003). The difference between outdoor and indoor has not been very pronounced in China according to Sirén (1948). An explanation of that, beside the relatively mild climate in big parts of the country, the Chinese has an unusual intimate connection with nature. They read nature in a different way than the western world.

When the officials eventually got restitution and returned to the city they recreated their dream of the rural detachment in their city gardens. The ones who created these garden ideals were amateurs. It was at the side of the job they worked in their gardens and wrote poetry (Svalin 2003).

Daoism

Daoism is a world view where the Daoist wants to be a part of the nature, let it flow through oneself, not only watch (Svalin 2003). Daoist's believe in eternal unity of all things in nature (Rogers 2001). You should not do anything without exercises *wu wei*, the non-conduct. By disappearing into gardens, hike to the mountains far away and seek plants for immortality the Daoist thought that they could find

the source to a very long life and perhaps even be one with the cosmos (Svalin 2003). The Daoist concept of transcendental, qi, means 'the breath' that enlivens all things (Rogers 2001).

The mushroom and the gourd are symbols for Daoism Svalin (2003) explains, they can be seen in gardens and paintings. The mountain that awakes and stimulates and the water that still, reflects and gives peace represent together the opposites of Daoism, yin and yang, and the interaction between them (Svalin 2003). In the practical work and the life in the garden, Daoism could be found here and there; as a symbol, a way to organize the garden or customary practice in the everyday life. To design what is not there but always current is what they wanted to achieve in the Chinese garden (Svalin 2003).

Feng Shui

In Daoism feng shui is something to endeavor, it is a universal force which follows a system of lines and flows through everything according to Svalin (2003). Rogers (2001) explains that feng shui means 'wind' and 'water'. To live in harmony with these forces you have to relate to those lines and place everything; yourself, the cities, buildings, furniture and gardens in the right spot and find harmony between what should be placed, the surroundings and cosmos. A force to beware of though is the evil spirits. In that they only move in one direction, a wall or a sick sac bridge in the garden could distract the force (Svalin 2003). Therefore the Chinese gardens, as Sirén (1948) explains, cannot be overviewed from a certain point. They consists of smaller isolated sections, but are connected to each other in a uniform composition. They have to be gradually discovered and enjoyed individually as the observer continues the walk through the garden (Sirén 1948).

According to Feng Shui requirements, built environment has a North-South direction with a Central Axis (Chen 2013).

Buddhism

Buddhism came to China 200s AD from India (Svalin 2003). Through meditation and self-quest you could be enlightened and come to understand the world, reach a nothingness, an emptiness. Emptiness in the meaning of no boundaries, clean, unconditioned happiness in the world essence has repercussions for the garden. All forms do not have any form and emptiness is the same as form Svalin (2003) declare.

Unlike the other teachings Buddhism was a religion and had a developed monasticism (Svalin 2003). The beautiful monastery gardens became the people's gardens, a haven where one could escape the bustling world outside. Buddhism, but also Daoism, expresses the ideal of complete human integration with nature (Rogers 2001).

The lotus flower (*Nelumbo nucifera*) is one of the heritages of the Buddhism. In the garden it expresses the divinity and purity in the core of all beings according to Svalin (2003). The Buddha is often pictured sitting on a giant lotus leaf or blossom (Ignatieva¹).

Religions/beliefs

- Confucianism
- Daoism
 - Feng Shui
- Buddhism

Classical ornaments on the roof protect the house



Culture and symbolism

The essence of Chinese art, architecture and literature are deep symbolism and spiritualism. For example, Chinese palaces, temples and mansions have monstrous zoomorphic ornaments, called wenshou, which are able to deal with magical power to conjure a downpour to put out a fire. Emperor's urban palaces and huge urban complexes are designed according to laws of cosmology: heaven is a circle and earth is a square (Ignatieva¹).

Symbolism can also be found in colors. Yellow is the royal color and is used exclusively by the rulers. It also represents the Yellow River - cradle of the Chinese civilization. Blue is the color of heaven and red is the color of festivity (Ignatieva¹).

Reflection of traditional garden culture and symbolism in modern green spaces

Features of Classical Chinese garden principles can still be seen in most modern public parks in China. In the overall design, Feng Shui principles are appearing, such as orientation and axis. Elements from the classical Chinese gardens are also found in the modern parks; water bodies, rocks, bridges, framed and borrowed views, winding corridors, architecture in classic Chinese style (such as pavilions and pagodas) and paving with “health paths” of stones. These are elements which also recur in the small scale proposal.

North-south axis



Openings in the wall that give a further glimpse, City wall park



Vaulted bridge found in Daming Palace

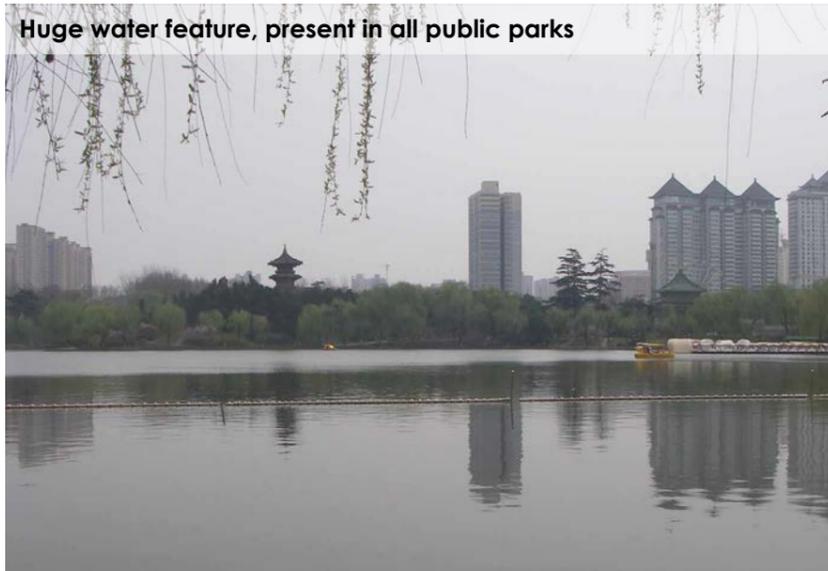


Spiritual rocks found in Xingqing Palace park



Health stone path found in City wall park







Of all the ancient capitals in China, Xi'an is considered the oldest one and the one that has been a capital for the longest time (Wang 2007). It was, furthermore, the first city that reached a population of one million inhabitants in China. Nowadays, the population has reached approximately 8.5 million people and it is the largest city in Northwest China (China Global Education Services 2014). In Zhou and Qin dynasties, Xi'an served as the political, economic and cultural center of China (Wang 2003). It was here in Xi'an, during the Qin Dynasty, the country became unified (Wang 2007). This took place during 200s BC (Cassel 2008). In the millennium that followed, Xi'an beheld the rise and fall of both Han Dynasty and Tang Dynasty (Wang 2007).

Xi'an is most known for the terracotta warriors and horses of the first Qin Emperor and its ancient city gates (Wang 2007). According to Wang the city has got a reputation for being China's "Natural History Museum", because of the many protected national heritage sites, such as the city wall, historical sites and palaces and over 4000 ancient mausoleums. He also records that the terracotta warriors has earned its place in the list of UNESCO World Culture Heritage Sites.

Another cultural symbol of Xi'an is the ancient city wall (Wang 2007). As stated by Wang it is the largest and most well preserved city wall of China today which dates back 1400 years and features a series of military installations, such as the moat, the suspension bridge, the floodgate building, the archer's tower, main tower, watchtower and parapet. It is also the starting point for the famous Silk Road (Jin 2008).

The rich historical and cultural heritage of Xi'an shows many relics and historical sites (Wang 2003). Walking along the city roads, you see fragments from different emperors more than a thousand years ago. The built structure of Xi'an started out as a geometric square and expanded in Tang Dynasty with a huge scale grid pattern where vertical and

Figure 5. Map of China.



horizontal road systems tied the city together (Xiu 2015).

According to Wang (2003), Xi'an is nowadays a city transforming itself into a modern metropolis with a great setup of commerce, trade, tourism, science, technology and education.

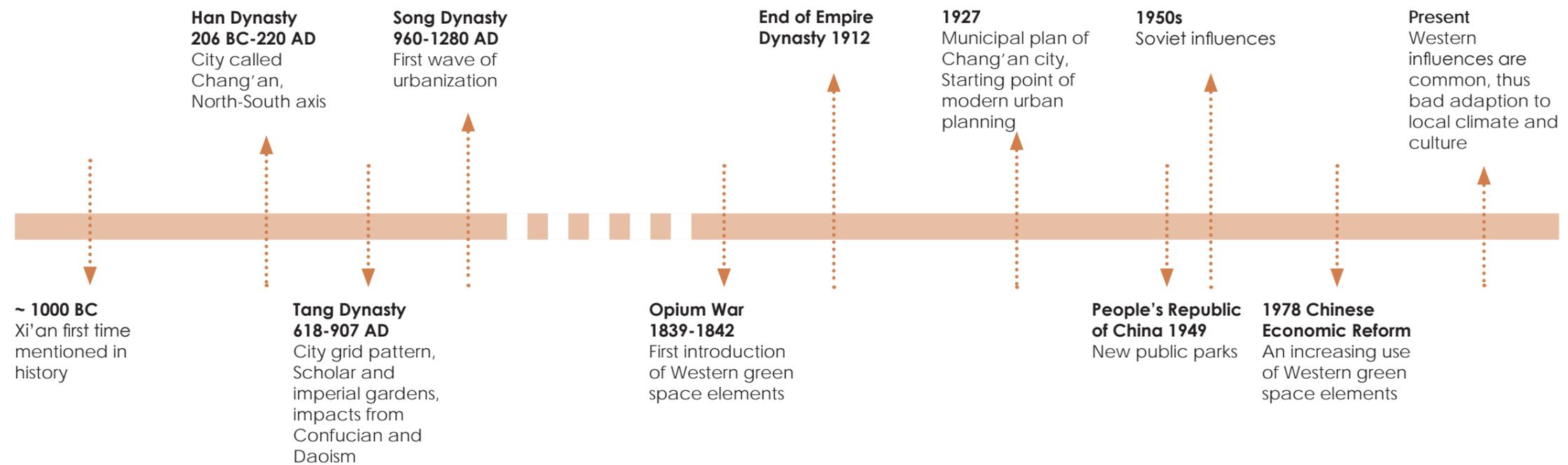
Environmental conditions

The city of Xi'an is located on the eastern hinterland on a flood plain by the south edge of the Loess Plateau, in Shaanxi province (Jin 2008). This site was chosen to build the city because of its fertile land, abundance of natural resources and sufficient water supply (Wang 2003). South of Xi'an, Qinling Mountains emerges, as a hundred-mile chain, and smaller branches from the Yellow River (the Wei, Jing, Chan, Ba, Feng, Hao, Yu and Lao rivers) run through the city. Back in the days, the range of skirting mountains furthermore made the site militarily formidable, explains Wang (2003).

There are four distinct seasons in Xi'an where climate, temperature and weather vary a lot (Xiu²). The warmest months are though, June, July and August with an average temperature of 25°C (World weather and climate information 2014). Xi'an is located in the arid and semi-arid region of China with a very low annual precipitation (Ling 2015). The rainiest season is, though, in September and the average precipitation over the year is between 500-600 mm. Further settles that the driest period is between December – February and the coolest month is January.

² Na Xiu, PhD in Landscape Architecture, Swedish University of Agriculture Science, meeting 2015-02-09.

Figure 6. Shows a timeline of the history of Xi'an green infrastructure.



Summary of the GI history of Xi'an

Xi'an's history goes back more than 3000 years and has experienced both Emperor Dynasty to democratic revolution to modern urbanization (Xiu 2015). She explains further that the main planning theories have been Daoism, Confucian and Fengshui.

Han Dynasty (206 BC-220 AD)

Xi'an, so-called Chang'an in emperor dynasty before 1911 (Jin 2008), was during the Han Dynasty given a symbolic significance because of its location and layout (Han & Zhao 2010). The city is surrounded by three sides of water and one side of mountain which is a pattern that from Fengshui perspective, it is called 安 (an) and means stability (Xiu 2015). The city was therefore named Chang'an which means long-term stability. According to Han & Zhao (2010) it is one of the most suitable places for building a capital city. During this era, due to fast economic development and stable society, peace and prosperity appeared for the first time in Chinese history (Jin 2008).

Green structure was something for privileged royal families and

consisted of landscape gardens in palaces, according to Jin (2008). A north-south axis symbolized the linkage between earth and heaven (Yi 1981). Every garden was designed by human and looked naturalistic (Xiu 2015). Water had the same important role as the green areas and Daoism played a significant role for the appearance. Further means that all ideas of Daoism could be found in the landscape gardens, such as sustain harmoniously ordered universe, pursuit of eternal life, naturalness, respect of the rules of development and advocate the harmony of humans and surroundings. Green space pattern adopted a natural and organic look unlike the city's regular and geometric structure, according to Xiu (2015).

Tang Dynasty (618-907 AD)

The Tang Dynasty was a remarkably powerful and flourishing period and lasted for 289 years, which is one of the longest dynasties in China's history (Jin 2008). The city structure was still symmetrical with its grid pattern and central axis (Yi 1981). But green structure was no longer just a privilege for royalties, as literal scholars began to design their own gardens (Xiu 2015). Still, royal and scholar gardens were inspired by

the organic natural style and ideas from Confucian and Daoism had an increasingly impact on the appearance of gardens in Xi'an.

In this era green structure also occurred as boulevards in form of street trees and in Xi'an, all streets and roads were planted with pagoda tree (*Sophora japonica*), willow tree (*Salix babylonica*) or elm tree (*Ulmus pumila*) (Yi 1993). The road greenery was managed and maintained by a special state office and people believed that street trees provided good moral behavior and blessing to the citizens (Chen 2013).

End of Empire Dynasty (1912 - present)

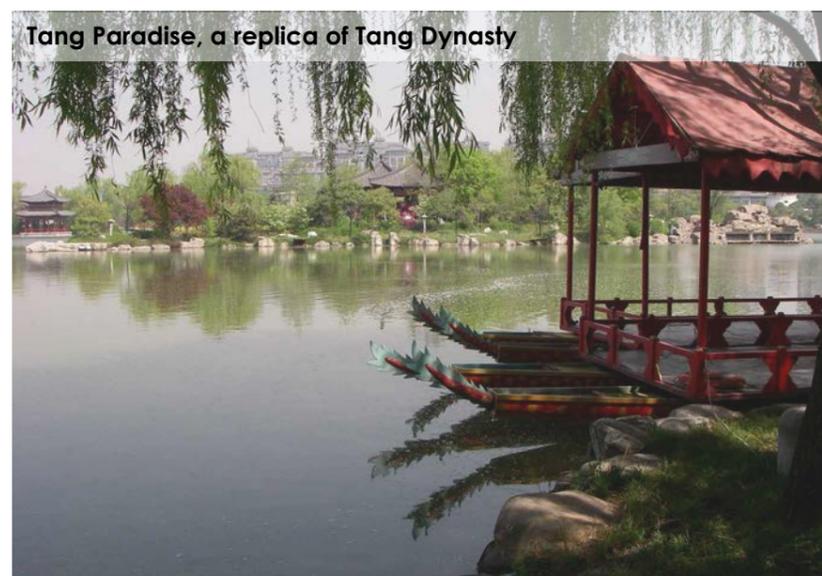
The starting point of modern planning in Xi'an was set in 1927 when the Municipal plan of Chang'an city was made (Xiu 2015). In the following period, the green structure in Xi'an would be affected by many different theories, from zoning theory, to Soviet model and traditional western theories (Chen 2013). Many western elements were though, imported without any adaption and the original and essential Chinese theory was lost in decades (Xiu 2015). At first, it was the zoning city plan which divided the city into different zones, for

instance, ancient, administration, commercial, industrial, agriculture and scenery areas (Long 2010). It was, according to Long (2010), inspired by Le Corbusier and a zoning plan was implemented and applied without any adjustments.

Green structure was also influenced by Soviet Union when public parks were seen as an effective tool for the government to provide civilized manners (Shi 1998). The first specially designed park of Xi'an was the Revolution Park, constructed in 1927, and served as a memorial park of soldiers and civilians death in the war (Xiu 2015).

The first master plan of Xi'an (1953-1972) for green area development adopted the typical Soviet model, the Park of Culture and Recreation model, which comprised green spaces for working class (Zhao 2009). The second master plan (1980-2000) categorized the resident areas into districts, street offices and neighborhoods. At this time, there was a green belt alongside the ancient fortification of Ming Dynasty called the Ring Park (Xiu 2015). The third master plan (1995-2010) established new spaces for urban development and created an environmental protection system for the original inner city (Long 2010). Citizen's need for parks were taken into consideration and in 1994 the first recreation park for ordinary working people was constructed (Fangzhi Park) and in 2004 a City Sports Park was created to encourage outdoor activities and improve physical health of citizens (Xiu 2015).

In the ongoing fourth plan (2008-2020) the main stress, regarding ecological protection, are connection and co-development of urban and rural areas (Zhao 2009). Green space planning and management are also important issues promoting more neighborhood green space, road greenery and city greenery from nurseries, according to Xiu (2015).



Tang Paradise, a replica of Tang Dynasty



Tidy lawns in Xi'an, western influence



Revolution park



Enormous flowerbed in Xi'an, western influence

Common plant material

China has got one of the richest floras in the world. Most of the species are native, but many of them are very common global plants as well (Ignatieva 2011). Further lists some of the most important trees and shrubs in China. The species are also common in Xi'an:

Table 4. Presents the most important trees and shrubs in Xi'an and China.

| Latin name | English name |
|-------------------------|------------------------------|
| Bambusa spp. | bamboo |
| Ginkgo biloba | ginkgo |
| Juniperus chinensis | juniper |
| Koelreuteria paniculata | goldenrain tree (China tree) |
| Lagerstroemia indica | crape myrtle |
| Osmanthus fragrans | sweet osmanthus |
| Pinus bungeana | pine |
| Pinus sinensis | pine |
| Platycladus orientalis | chinese arborvitae |
| Prunus communis | plum |
| Prunus mume | plum |
| Prunus persica | peach |
| Sophora japonica | sophora |
| Trachycarpus fortunei | windmill palm |

Other common species in Xi'an:

Below, other common trees and shrubs that represent the green infrastructure in Xi'an are listed.

Table 5. Presents other common tree and shrub species in Xi'an.

| Latin name | English name |
|---------------------------------------|----------------------|
| Acer palmaatum | japanese maple |
| Ailanthus altissima | tree of heaven |
| Berberis thunbergii var. atropurpurea | berberis |
| Buxus sinica | box |
| Cedrus deodara | deodar cedar |
| Cercis chinensis | chinese redbud |
| Euonymus spp. | euonymus |
| Kerria japonica | kerria |
| Ligustrum lucidum | privet |
| Ligustrum vicaryi | privet |
| Magnolia spp. | magnolia |
| Metasequoia glyptostroboides | sequoia |
| Nandina domestica | nandina |
| Paeonia suffruticosa | peony |
| Photinia x fraseri | photinia |
| Phyllostachys viridis | bamboo |
| Pinus tabulaeformis | pine |
| Pittosporum tobira | japanese pittosporum |
| Paulownia | empress tree |
| Platanus acerifolia | plane |
| Prunus cerasifera | plum |
| Punica granatum | pomegranate |

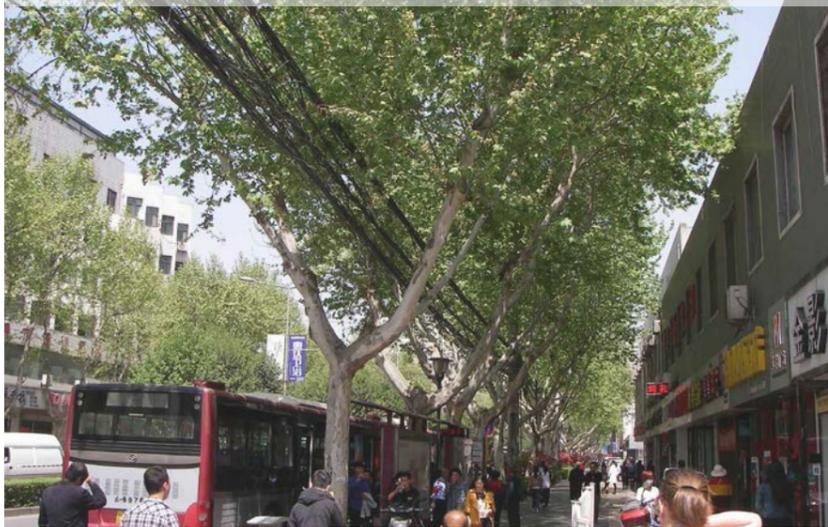
| Latin name | English name |
|-------------------------------|--------------|
| Pyracantha fortuneana | firethorn |
| Rosa ssp. | rose |
| Salix babylonica | willow tree |
| Sophora japonica var. pendula | sophora |
| Syringa ssp. | lilac |

Some of the plants are associated with the countryside, for example *Paulownia*. Especially in areas of 1970's, 1980's and 1990's, many *Paulownia* were observed, and also *Ailanthus altissima*. In sites created in 2000's, there are more global plants such as *Prunus cerasifera* and *Ligustrum lucidum*.

Common trees that are used in the streets are for example *Platanus acerifolia*, *Sophora japonica*, *Ginkgo biloba* and *Cedrus deodara*.



Platanus, common street tree in Xi'an



Prunus mume, common decorative plum tree



Today's planning framework

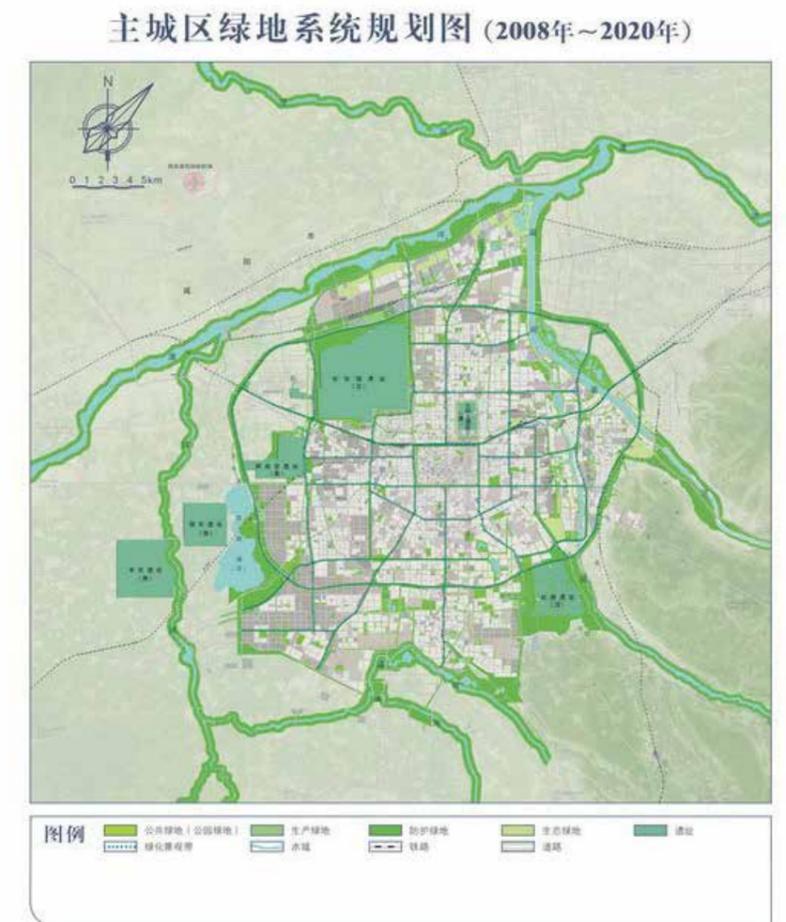
The municipality of Xi'an has created different kind of urban development maps, with the aim to make the city more sustainable. Further, four different municipal maps are presented; green space planning map, main zoning map, current land use map and land use planning map. Unfortunately, the quality of the maps one find at the municipality's webpage is poor.

The green space planning map (Figure 7) shows, though, that the linkage between rural and urban areas is enlightened and the river has gained importance for the city. They have also ticked out green spaces for environmental protection and ecological green spaces for example.

The main zoning map (Figure 8) shows how different districts are planned to further develop into for example tourism areas, commercial areas and new technology industrial areas. The green arrowed lines show how a greenery belt could be developed in the city.

Current land use map (Figure 9) illustrate in detail different areas in the city and their function today, such as resident area, educational area, culture and recreational area and public green space. The land use planning map (Figure 10) shows how the city can expand and with what type of purpose. For example, the city will expand with a lot of new residential areas as well as educational and industrial areas. There will also be some smaller new areas for public green space.

Figure 7. Green space planning map of Xi'an.
Source: Xi'an City Planning Bureau 2007.

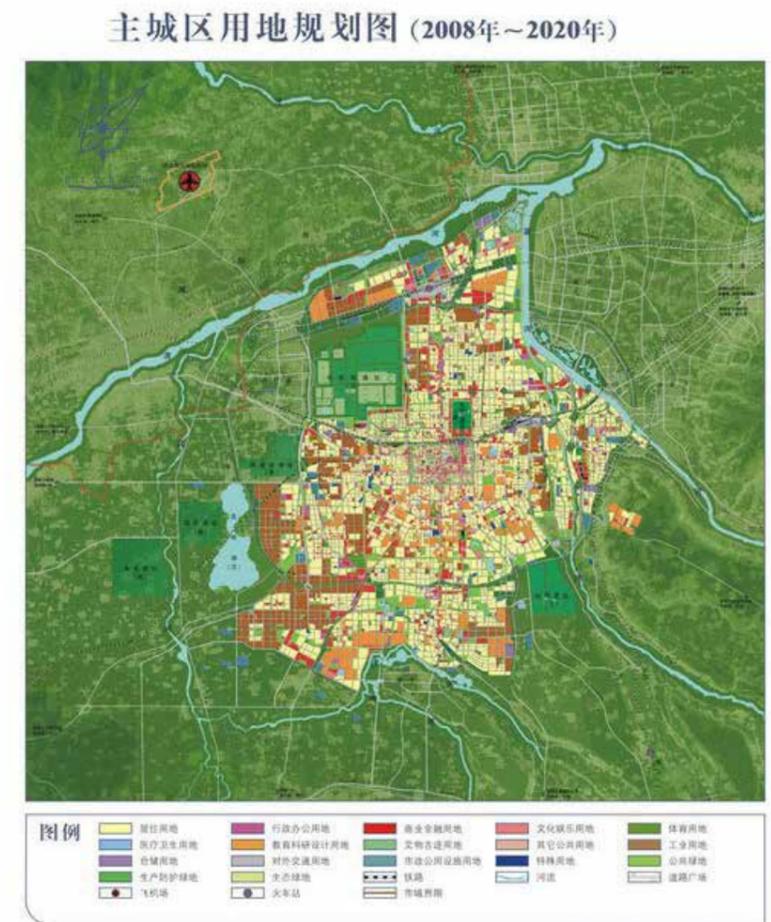
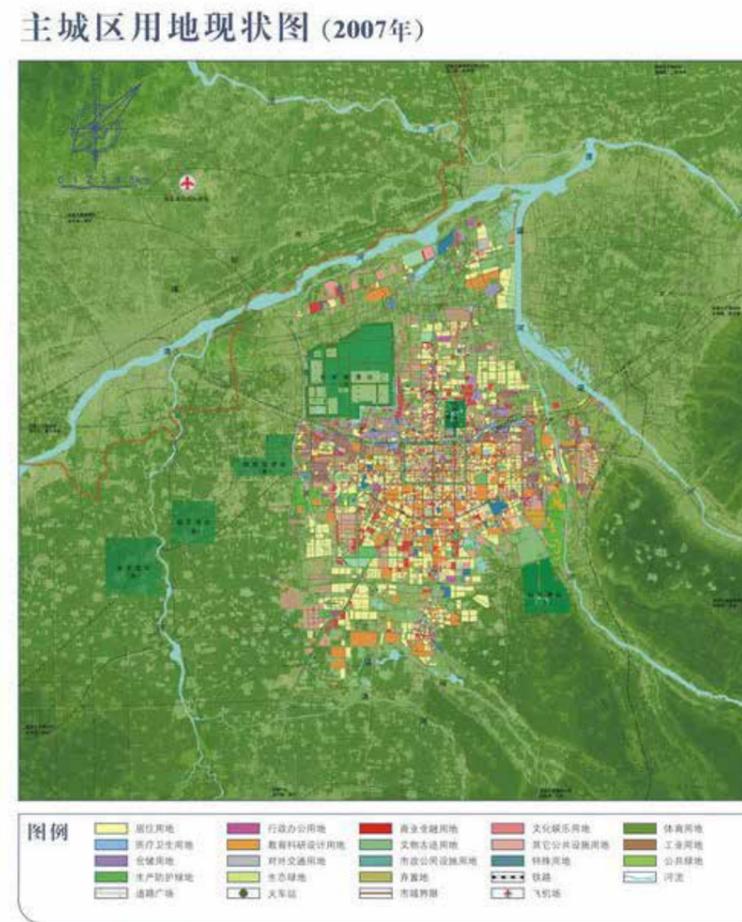
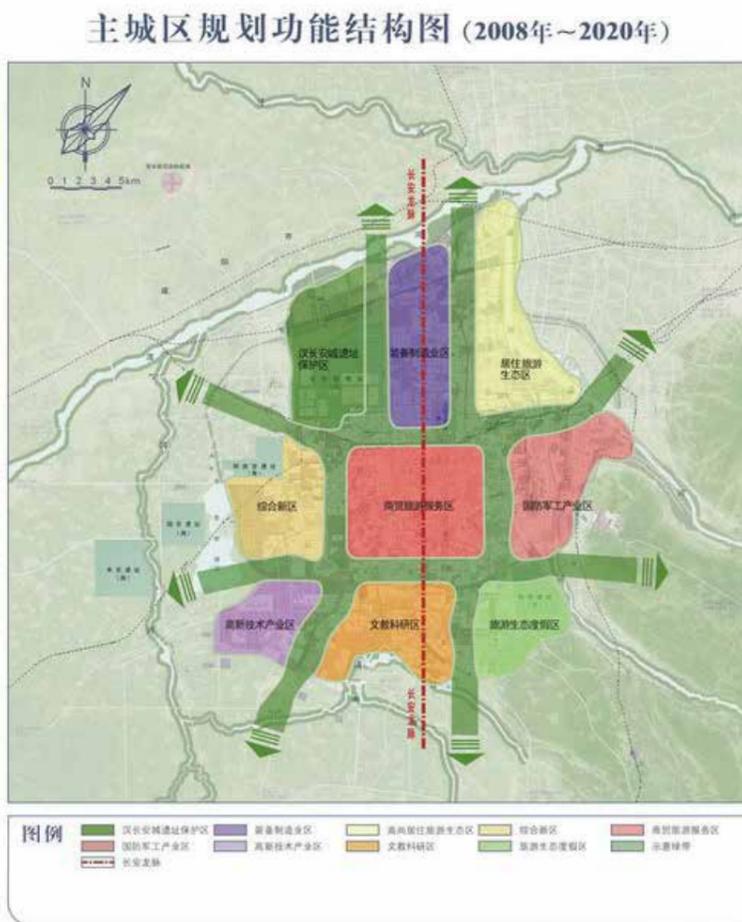


| | | | | |
|--------------------|------------------------|--------------------------|------------------------|-----------|
| Public green space | Productive green space | Environmental protection | Ecological green space | Antiquity |
| Greenery belt | Water | Railway | Road | |

Figure 8. Main zoning map of Xi'an.
Source: Xi'an City Planning Bureau 2007.

Figure 9. Current land use map of Xi'an.
Source: Xi'an City Planning Bureau 2007.

Figure 10. Land use planning map of Xi'an.
Source: Xi'an City Planning Bureau 2007.



Heritage area Chang'an Industrial area High-building resident ar. Newly developed area Commercial area
Military area New techn. Industrial area Educational area Tourism area Landscape greenery belt
City boundary

Resident area Administration area Commercial area Cultural recreational area Sports area
Hospitals Educational area Antiquity Other public area Industrial area
Storage area External roads Public facilities Special purpose area Public green space
Productive area Ecological green space Abandoned area Railway Airport
Square and road Railway station Boundary

Resident area Administration area Commercial area Cultural recreational area Sports area
Hospitals Educational area Antiquity Other public area Industrial area
Storage area External roads Public facilities Special purpose area Public green space
Productive area Ecological green space Railway Airport
Square and road Railway station Boundary



INTERVIEWS

This chapter includes a summary of the interviews made with a politician, professors and a city gardener during the field study in Xi'an. Fully interviews can be found in Appendix 3.

SUMMARY INTERVIEWS

Professors

The green infrastructure is an important fundamental element Dr. Ling says, especially for developing counties. Because of the sacrifice of many natural resources we need to find a balance between the economic development and the natural conservation. You could say that the green infrastructure is sick at the moment, and by using ecological ways to make it sustainable and build a network, we can make the cities healthier, she says. Her vision is to implement more greenery in the cities in the future, especially lawns, meadows, vertical gardens and roof gardens. To use sustainable material and native species is also a good start to achieve sustainable urban development, according to Dr. Qiu Ling.

To implement ecological design in public green spaces would definitely be necessary and a smart way to develop the urban greenery, according to Dr. Ling. The social aspect is very important too, but one is not more important than the other, so combining these two aspects would be a good way to make the green infrastructure development successful. The first step to build green corridors or a green network in the city would be to collect basic data's about the different green spaces and value it from an ecological perspective. Virtual mapping is a good way to do it, she says.

Xi'an's green infrastructure is definitely not fulfilling the ecosystem services. The green infrastructure is also fragmented, she continues, because the decision makers and developers don't have an overall picture of how the city should be planned.

The most important function the green infrastructure has in the cities, according to Professor Li, is to decrease the dangerous gases. His vision is to enlighten the people and the government so they will be aware of the damage of the ecosystem the man is causing, and for somehow prevent it. He explains that the biodiversity in Xi'an is poor and the air

quality is even worse.

Professor Li means that the buildings and the cars are taking too much space and there are no room left for the vegetation. He thinks there are great opportunities to increase the urban green infrastructure and implement ecological designs in Xi'an. But the way it should be done is with green walls and green roofs because of the lack of space between the buildings.

Rain gardens do not exist in Xi'an now, but it is something to strive for to apply in the city. There are some ecological projects going on but they are not finished. The designers want to implement more ecological design, but they cannot fulfill the design because they don't have enough knowledge and very short of time in the projects.

There are designers working with a plan for the green infrastructure in the city but it is not finished yet, according to Professor Ji.

Recreation, ecology and economy are the basic values of the green infrastructure according to Professor Ji. She thinks the green infrastructure in Xi'an is "destroyed" and has to be improved. People should wear a mask when they are outdoors to protect themselves from the bad air conditions.

City gardener

Mr. Yu's opinion of ecological design is low technology dependent and the natural system perspective. To apply the ecological design the local conditions should be defined, for example the local history and culture. The Qujiang district is an example where it has been implementations of ecological designs.

The most important thing about a sustainable city, according to Mr. Yu, is to have a resilient city that could heal itself. His vision is that

the green infrastructure will be improved in Xi'an. The city gardeners and the city planners should introduce more modern thinking and technologies in their daily work, for example GIS.

The most important issue is how to connect the green existing areas with each other. But there are a lot of old buildings so they have to implement green areas in another way than on the ground so they don't have to tear down the houses, for example by green roofs and green walls.

Politician

Mr Zhou's understanding of a sustainable city is to educate more landscape architects to have more people in the business to increase the greenery. The political vision is to become a forest city and to reach that they have to increase the greenery inside the city wall.

The municipality policy is to make Xi'an a forest city, now it is a garden city, meaning they seek to make Xi'an a greener city in the future. They are planning to build 10-20 new green areas in the city every year. The goal is that all citizens should have access to a green area within fifty meters from their home. 40-50 percent of green areas are a standard for a garden city, and in new projects the amount should be at least 40 percent to be approved by the government.

The view of green infrastructure is not the same in China as in the western world. He says that the green infrastructure is related to the landscape greenery and has a big aesthetic value; it is like accessories to the city.

Mr Zhou thinks the green infrastructure is more important today than 20 years ago, and it has been improved because of the use of more species. The politicians are paying more attention to the green infrastructure nowadays because of the environmental problems.



BIG SCALE

This part describes the big scale approach of this master thesis. It shows further the results from inventory and analysis of Xi'an green infrastructure as well as enlightens opportunities for how the green infrastructure in general can be developed in a sustainable manner for a sustainable city.

CASE STUDY XI'AN

The case study of Xi'an aims to identify and evaluate the present main features of Xi'an green infrastructure. The results are displayed in different maps with associated descriptions.

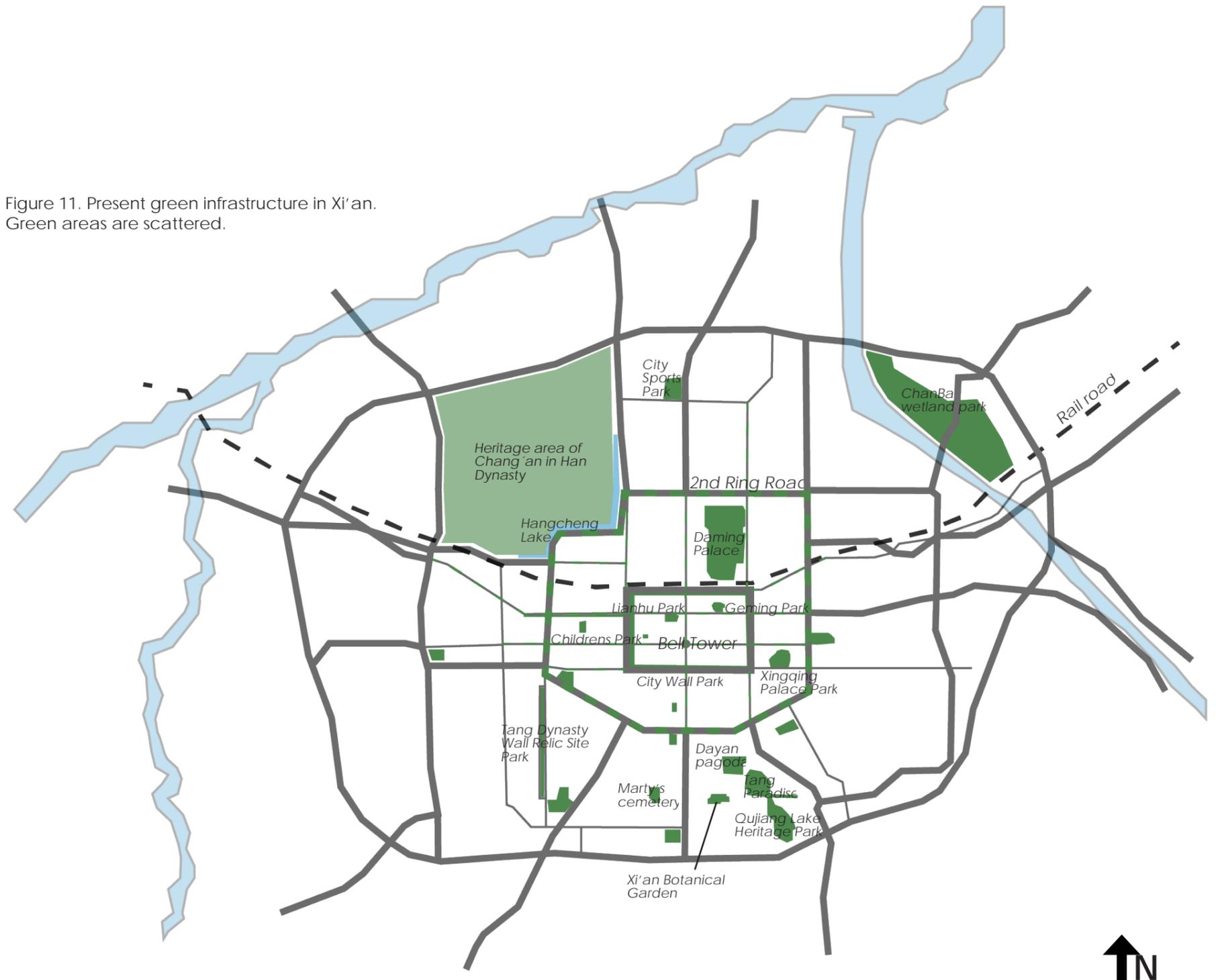
Inventory

By studying several comprehensive maps of the city Xi'an and its' green infrastructure, we found that the green structure is quite fragmented. We made an identification of the main green spaces in the city and divided them into different categories with Ignatievas¹ subdivision of Xi'an's green areas as the basis. The categories are: *public parks, trees and vegetation along the streets, green areas inside neighborhoods, green parade plazas in the front of important historical monuments, environment next to educational campuses and governmental institutions and cemeteries*. So within the city, except for the green corridors along the streets, green spaces are fragments scattered in the city with no connection to each other. Further follows an explanation of our categories.

Table 6. Our classification of Xi'an green infrastructure.

| Classification of green areas in Xi'an | |
|--|---------------------------------------|
| • Public parks | |
| | <i>Recreational parks</i> |
| | <i>Historical parks</i> |
| | <i>Ecological demonstration parks</i> |
| • Trees and vegetation along the streets | |
| • Green areas inside neighborhoods | |
| • Green parade plazas in the front of important historical monuments | |
| • Environment next to educational campuses and governmental institutions | |
| • Cemeteries | |

Figure 11. Present green infrastructure in Xi'an. Green areas are scattered.



Categorization of green spaces

We classify the main features of Xi'an green infrastructure into six different categories.

Public parks

Attractive places for the inhabitants with great significance as a big and coherent green area in the city. The parks are very well used and highly maintained. There are a big amount of artificial water features in the parks as well, and a lot of artificial rocks and rock constellations.

Recreational parks

There are several recreational parks in Xi'an. The variation of species is big and there are a lot of flowering trees and shrubs. Many of the green surfaces often have bare grounds and there are a lot of wear due to the highly used areas.

It is rarely the parks are empty (during its opening hours). People do all kinds of activities from early morning to late evening. Activities occurring are for example playing instruments, dancing, playing music, singing, reading, painting, taking photos, exercise in outdoor gyms, exercising sports like badminton, ping pong and tai chi etc.

There are also different spaces where there are playgrounds, amusement parks, boat rentals, smaller shops, indoor aquariums, movie theatre, ghost house etc.

Historical parks

There is one historical park in Xi'an, the Daming Palace National Heritage Park. It was once the imperial palace of Tang Dynasty serving as royal residence. Today it is redesigned as a public park and covers an area of 3,5 square kilometer. It is one of the newest parks in Xi'an and was open to the public in 2010. It was the Chinese government who did the effort to restore this place. Before it was a big slum area and

Recreational public park



Historical public park



the lake was just a waste collection space. This park does not have the same richness of species as the recreational ones. It is a huge amount of big open spaces with lawns compared to the rest of the city and a lot of trees. The entrance part is an enormous hard paved area and is for example used by the locals to fly kites. Exhibitions of historical relics and memorials are found and there is one part of the park with excavations that is fenced and you have to pay to enter. An artificial lake is located in the middle and it is along the lakeshore you can find the more ornamental areas.

Ecological demonstration parks

Xi'an also have parks which are focused on the ecological sustainability and development, Hancheng Lake and ChanBa National Wetland Park are two examples.

Ecological demonstration park, ChanBa



Hancheng Lake is a national science and technology demonstration park of soil and water conservation of the Han Dynasty capital city lake. It aims to popularize the knowledge of soil and water erosion hazards and conservation, display the great achievements of the conservation management, improve whole people's consciousness of cherishing water and soil resources, protecting ecological environment and conserving soil and water.

ChanBa National Wetland Park is located at the confluence of two rivers, the Weihe and Bahe rivers, and integrates the eco-landscape highlights of both waterways to form an important wetland ecosystem. The park contains typical estuarine wetlands including swamp wetland, island and swamp wetland, lotus-pond wetland, dry ditch wetland, sand bay wetland and a steam wetland. Here they demonstrate biodiversity and the coexistence between man and nature.

Trees and vegetation along the streets

Green corridors within the city. It is substantially the main streets; South, North, East and West Street (Nan Dajie, Bei Dajie, Dong Dajie, Xi Dajie), which have the biggest amount of street vegetation, both shrubs and trees. The main streets are quite broad and most often at least four rows of trees but sometimes even six rows. The most common tree species along bigger roads in Xi'an are *Sophora japonica*, *Platanus acerifolia* and *Ginkgo biloba*. The undergrowth is mostly bushes but there are summer flowers placed there too. They are highly maintained areas. In some places, especially along the Second ring road, there are broad stripes of vegetation between the lanes and there are often a lot of conifers.

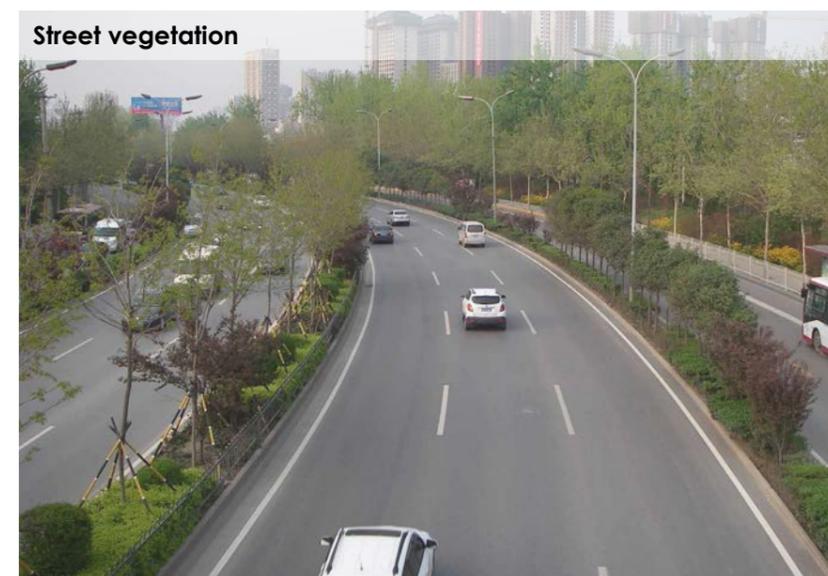
These green areas do not benefit the people in a social perspective; they are not accessible and not built for people to staying there. There are though, in two sites, narrow strips of parks in between the lanes with a lot of trees and shrubs, allowing people to take a stroll in a very long

slender park. While inside, you are not actually disturbed by the traffic.

The alleys often have the same tree species but it can vary between the rows and the different streets. The under growth has a little more variation of species richness but it is often a recurrent pattern. For example *Photinia x fraseri*, *Pittosporum tobira* and *Oxalis corymbosa* are used.

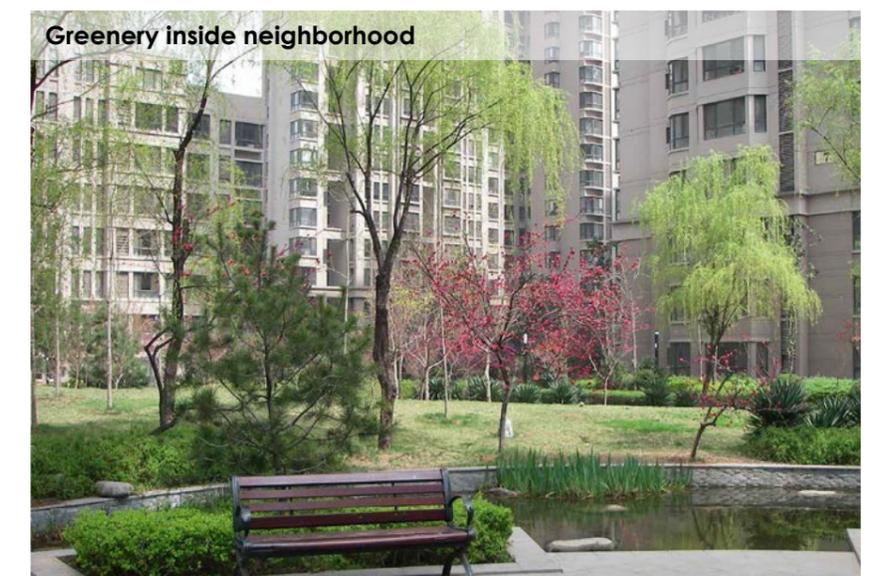
Green areas inside neighborhoods

The newly built neighborhoods often have a high amount of greenery. The gardens are rich of species, but mostly trees and shrubs, not very many kinds of ground covering species. There is plenty of flowering vegetation in many different colors (for example *Prunus mume* and *Prunus persica*) and there is often some kind of water features inside the neighborhoods, ponds and fountains are often found. Western influences, such as lawns, are also common.



The neighborhoods are attractive places for the people who lives there but also for their family and friends. You can find playgrounds for the children, outdoor gyms, sometimes ping pong tables and basketball plans. There are also places with the opportunity to sit and relax with the surrounding greenery. The neighborhoods are very well used and the vegetation is well preserved. The greenery in neighborhoods is also very well maintained. Most of the neighborhoods though are gated communities, only accessible for the residents.

The greenery varies a little bit though depending of construction year. Neighborhoods from the 1970-1980s have a limited amount of green areas for the residents, but in the 1990s they grew to a reasonable size (Ignatieva et al. 2015). And in the 2000s-2010s, the green areas became big inner yards. In the most recent neighborhoods there are a lot more designed areas with standardized lawns, hedges, ground covers and topiary shrubs, thus more Western influences of green space elements.



Green parade plazas in the front of important historical monuments

Places with ornamental plantations and vegetation. There are often bigger lawns prohibited to step on and summer flowers which are changed during the season are common. Pruned bushes in different shapes are often a part of the greenery. Large hard paved squares and water features are also occurring which can be very grand. These are very well maintained places.

These areas are highlighting for example an entrance, a special historical place or a monument or places where a lot of people pass every day. For example in front of pagodas, the city wall entrances, Bell Tower and the beginning of the Silk Road.

Environment next to educational campuses and governmental institutions

Lavish, grand facilities where high maintenance is needed. The vegetation consists mostly of topiary trees and bushes, and ornamental lawns in the space between and under the trees and bushes. At the sight there are also large hard paved squares and roads where cars can move through the area. Water features are also common and different ornaments can be found.

The campuses are most often covering a larger area and could have more elements of park than the governmental institutions. The campuses can also include places for activity such as outdoor gyms and sport facilities.

Cemetery

A green area where the greenery seems to be not as strict managed as other parks. Partly there are topiary trees and shrubs, for example where you can find gravestones and along some of the larger paths, but mostly the greenery has a wild character with no regular mowing.

Greenery by the historical city wall



Greenery in cemetery



Xijing University campus



In China the cemeteries don't have a gravestone for each person according to a local resident, it is too many people. Instead they have a memorial place where they can come to have a memory ceremony. This place is located in the cemetery park and defined by walls. There are also associated buildings within the cemetery area.

ANALYSIS

SWOT – Big Scale

Table 7. Displays strengths, opportunities, weaknesses and threats regarding the green infrastructure in Xi'an.

| | |
|---|--|
| <p>Strengths</p> <ul style="list-style-type: none"> The plantations in parks and streets are well maintained Three layers (trees, shrubs and groundcover) of greenery along the main roads Existing public parks are big Birdsong in the parks | <p>Weaknesses</p> <ul style="list-style-type: none"> Fragmented green infrastructure Lack of larger contiguous green spaces A lot of buildings A lot of hard paving Densely populated Not enough greenery in the city Existing green areas are exposed to great wear |
| <p>Opportunities</p> <ul style="list-style-type: none"> Existing green areas could be developed --> used in a better more effective way Increase the green infrastructure in the city Prevent consequences of lack of green infrastructure Improve the air quality Improve the ecosystem services Get more sustainable green infrastructure Build green corridors and a green network Improve the storm water management Decrease the temperature in the city by introducing green areas | <p>Threats</p> <ul style="list-style-type: none"> The air pollution increases The biodiversity and the ecosystem services decreases Not enough space to develop the green infrastructure More extreme weather conditions More cars, buildings and industries Prioritized economic development ahead of improving of the environment |

Lynch – Big Scale

Barriers: Xi'an city wall and the moat, Second ring road, East-, West-, South- and North Street and the railroad.

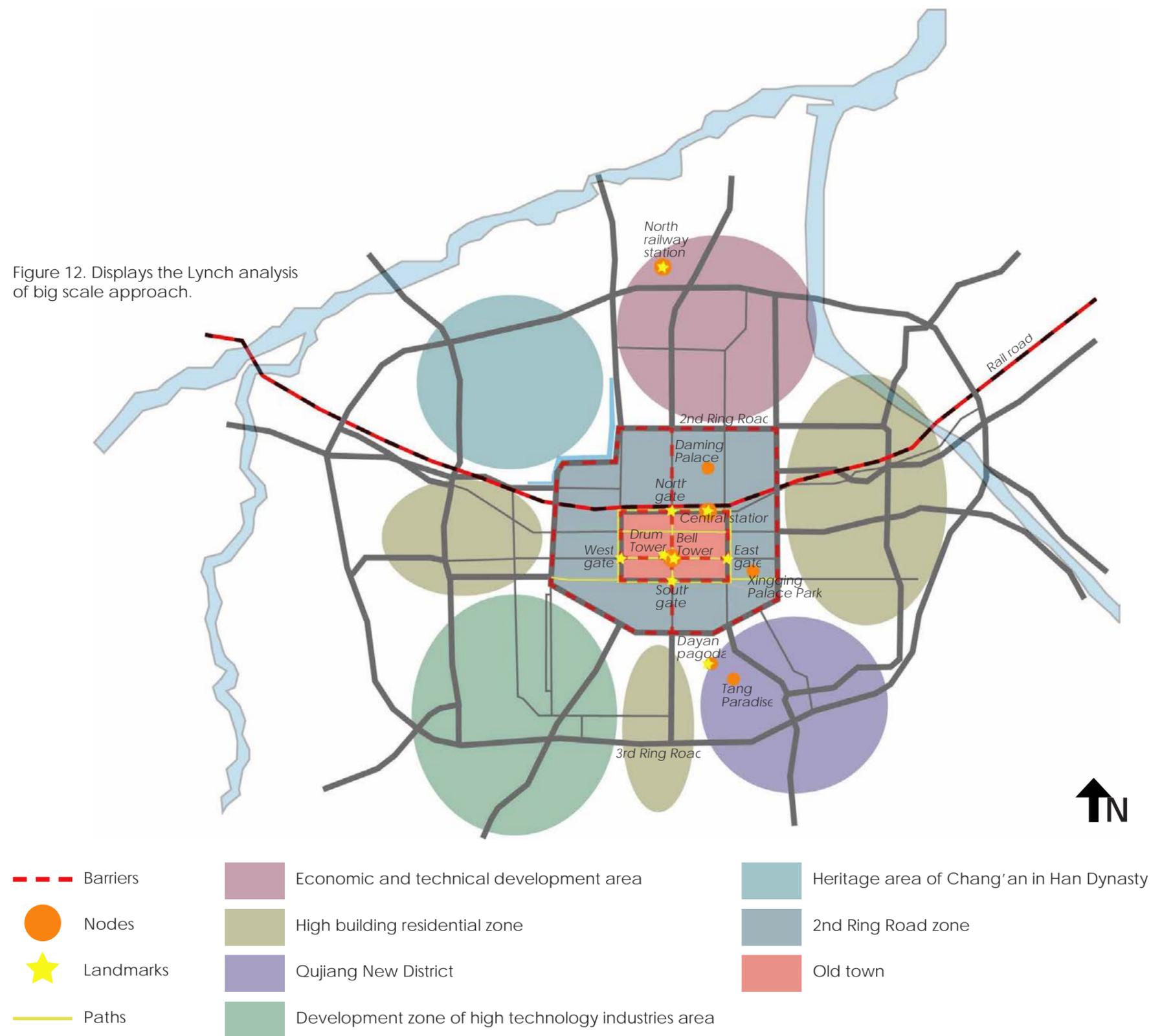
These places become barriers in the city because they all limit the accessibility of passing through. By the city wall you can only pass through a limited number of gates. There are fourteen ones along the whole wall. Where you can pass through the wall you can also get over the moat. The Second Ring Road is a big road that goes around the entire city, and with its heavy traffic it is hard to cross, even at the pedestrian crossings. East-, West-, South- and North Street are also barriers in the city. It is often a fence or a traffic island, with or without greenery, in the middle of the road. Instead of crossing the street you have to take the tunnel under it in certain places. The railroad is considered as a barrier too, because you cannot pass it except in some particular places.

Districts: Old town (inside the city wall), Second Ring Road zone, Heritage area of Chang'an in Han Dynasty, Economic and technical development area, Qujiang new district, Development zone of high technology industries area and High building residential zone. The city is divided into different districts with the help of a tourist city map combined with our own experience. Here follow a description on each district:

Old town (inside the city wall)

This district is Xi'an's central point and the oldest part of the city. This area do not have any skyscrapers, only lower preserved buildings. At the edge of this district the city wall and the moat surrounds the area. East-, West-, South- and North Street are the main roads in this district, rich of greenery.

Figure 12. Displays the Lynch analysis of big scale approach.



2nd ring road zone

In this area there are plenty of higher buildings and a large proportion of them are quite new or are still being build. The largest city park, the Daming Palace National Heritage Park, is located in the northern part of the district but there are also other popular parks in this area. East-, West-, South- and North Street with their greenery also runs through the area.

Heritage area of Chang'an in Han Dynasty

During the Han Dynasty this area was the center of Chinese economy, culture and politics for more than 200 years (Shaanxi Provincial Bureau, 2013). There were a lot of international exchanges taking place here and Han Dynasty Chang'an is therefore considered as China's earliest international metropolis. Under state protection this area is now an important heritage site in Xi'an according to Shaanxi Provincial Bureau (2013). Nowadays the area is rural with lots of cultivated areas, greenhouses and recycling and dump centers in between the historical relics.

It is a very open area with few buildings. The buildings that exist are small and mostly located along the main road through the area.

Economic and technical development area

According to National Economic and Technological Development Zones (2003), this area has an industrial structure. Light industries, mechanical electronics, foods, bio-pharmaceuticals and new materials are examples of pillar industries, these are driven by new and high-tech products and has come into shape in this zone. (National Economic and Technological Development Zones 2003.

According to us, this is a newly built area, which is still being built, with a lot of greenery along the streets. The area feels modern and more open even though it has a lot of high buildings. The openness may be due to more space between the buildings.

Qujiang new district



Qujiang new district

This area is a hyper-heritage development site, one of the country's most ambitious ones in recent years (Jaivin 2010). There is a project about transforming Xi'an into an international city and make it a cultural hub of China's northwest. Qujiang new district will be a National Cultural Display Zone, the hub of the hub, and combine tourism, leisure facilities, a diverse range of cultural and residential zones (Jaivin 2010). This was also the location of imperial lakes, relics and gardens which some of them are preserved today.

This new area contains lower constructions and more green spaces between the buildings. There are both apartment buildings and neighborhood areas with only private houses with associated private gardens. One can also find large parks within this district. It is a grand area with a lot of cultural places and buildings which attract a lot of tourists.

Development zone of high technology industries area

In this area the largest part of Xi'an's industries are located. According to Chinese Business World (2009) the industry has become during the recent years the most important growth point for the city's economy. This area is also one of the most developed districts in its planning and basic construction. The Xi'an Municipal government generate the rating of this area as a green-space model and by China's Construction Ministry there are two residential districts within this area which have been cited as exemplary units (Chinese Business World 2009).

This district contains areas of both high and low, new and old buildings. All the streets, especially in the newer areas, have a larger proportion of greenery than other parts of the city.

High building residential zone



High building residential zone

Both high skyscrapers and lower buildings are located in this area, but mainly higher buildings and many skyscrapers under construction. You can find residential buildings and office buildings, industries and parks. Most of the area includes newer buildings built in recent years. The larger roads account for the most greenery in this district.

Nodes: Bell Tower, the central railway station, the north railway station, Northern square of Dayan Pagoda, parks,

These places are nodes in the city where a lot of people gather and chose to dwell. Bell Tower is a central point in the city where four big roads meet and there are a lot of different shops and facilities. The railway stations are obvious nodes due to many people travel by train and Northern square of Dayan Pagoda is a big tourist attraction. The public parks are very popular places for people to meet, play instruments, paint, dance, exercise, play sports and take part in many different activities. The parks are the Chinese people's living room.

Landmarks: Bell Tower, Drum Tower, the city wall entrances (East, West, South and North Gate), Dayan Pagoda (Wild Goose Pagoda), the central railway station and the north railway station.

These are the most common landmarks in the city and they work as orientation points. Bell Tower is the most famous landmark according to us. It is located in the middle of the city and is a well-known spot in the area, easy to recognize and visible from a distance in four directions. A lot of people pass here from dawn to dusk, the place is rarely empty. By the four city wall entrances are the biggest roads in to the old city, a lot of people and vehicles are passing through here. Drum tower and Dayan Pagoda are two renowned places and a help to navigate in the city, as well as the railway stations.

Paths: all large roads, the city wall park,

All larger roads in the city work as paths, but East-, West-, North- and South Street are the main paths in the central area of the city. The city wall park that surrounds the old town outside the city wall is also an important path, but only for pedestrians.

Development zone of high technology industries area



PROPOSAL/GUIDELINES BIG SCALE



Figure 13. Shows concept sketches of guidelines for development of Xi'an green infrastructure.

Guidelines

- **Develop green corridors within the city along the main roads**
 - Develop street vegetation
- **Connect existing green areas to each other**
 - Green roofs
 - Vertical gardens
- **Develop green corridors that connect rural and urban areas**
 - Extend the existing road greenery from urban to rural areas
- **Develop the Ring roads as green belts**
 - Fill out gaps
- **Increase the ecological values in existing parks**
 - More native species
 - More ground cover instead of lawn
 - More rain gardens and other sustainable storm water management

Development of green infrastructure in Xi'an

Green corridors in urban areas provide pathways for dispersal of animals and plants. They also retain other ecological and landscape values (Ignatieva et al, 2008). To develop the green corridors in Xi'an, a framework for further restoration of the ecological values in the city would be established. Since the green areas in Xi'an are dispersed and with poor linkage between each other today, green corridors is a good way to connect them and improve the ecological values.

Due to the dense settlement there is not much space to expand or establish more large green areas in the city. That makes the already existing parks and green spots even more important to preserve and maintain. To increase the biodiversity and implement more ecological design solutions (green roofs, bio swales etc.) in the parks are therefore necessary. For example more native species could be used, scattered highly maintained lawns could be replaced by ground cover species and water features could be turned into sustainable storm water management.

The dense city also entails that green roofs and vertical gardens are more convenient solutions for Xi'an to increase the green infrastructure. Mr. Yu (interview 2015) says, based on current conditions in Xi'an, that the green roofs and the vertical gardens could be possible to apply in the city to further create sustainable green infrastructure. Mr. Zhou (interview 2015) states that Xi'an has a lot of old preserved buildings, especially in the city center, that is a shame to tear down. Therefore green walls and roofs can be used in the city to enhance the greenery and connect existing green areas to each other.

Except for the connection between the green areas within the city, the connection to the surrounding rural area outside the city is important as well. A rural-urban connection would increase the opportunities to



Streetscape in Xi'an



In a dense city, bigger streets can provide green corridors to the city. Besides ordinary street vegetation, green roofs and walls alongside can also enhance the greenery and connect the existing green areas.

develop a more ecological sustainable green infrastructure in the city thanks to the increasing pathways for dispersal of animals and plants. With an expansion of pathways there will be a higher amount of greenery in the city as well, which is beneficial for the air quality.

As mentioned above, it is lack of space for building new green areas. The space where the streets are is therefore a possible place to develop green corridors in the city. There are several large streets that range from the outskirts of the city and towards the city center, suitable

for establishing green wedges from urban to rural areas. A three level greenery is desirable (trees, shrubs, ground cover), with both deciduous and conifer species.

The Ring roads in the city, especially 2nd road and 3rd Ring road, have great potential to become green belts in the city. There is a lot of existing greenery already aside from a few bigger gaps. The gaps need site specific solutions but are able to strengthen the greenery as green belts if filled in with vegetation.

Streetscape rural area, poor GI



Green wall/vertical garden
Photo: Maria Ignatieva 2015



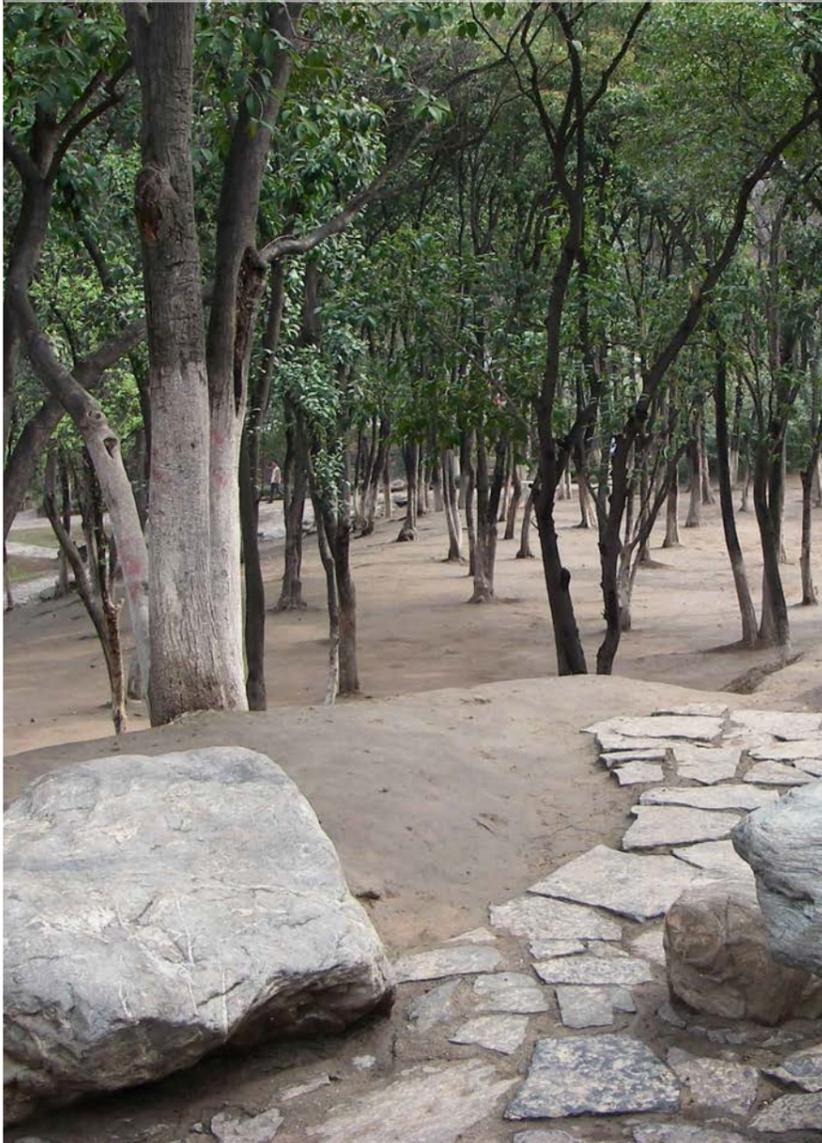
Gap in the green belt, 2nd Ring road



Poorly established lawn in public park



Lack of ground cover in public park



Iris, suitable as ground cover



Ecological storm water management
Photo: Maria Ignatieva 2014



Ecological bio swale in the park
Photo: Maria Ignatieva 2015



The background of the page features a low-angle shot of a building's facade, partially obscured by a dense canopy of autumn maple leaves in shades of red, orange, and brown. The leaves are in sharp focus, creating a textured, layered effect over the building's windows and architectural lines.

INTERMEDIATE SCALE

This part gives an introduction to the case study of Rongcheng, the intermediate scale approach, and presents the results of the observational study with further sustainable guidelines for how the green spaces in the neighborhood can be developed.

CASE STUDY RONGCHENG

This master thesis comprises a case study of a neighborhood in Xi'an. The chosen neighborhood is Rongcheng and the aim with the case study is to find out what ecological approaches that can be applied to create sustainable green spaces and create guidelines applicable to other similar neighborhoods.

Why Rongcheng?

We looked at different neighborhoods before we chose Rongcheng. The selection process is described in the method chapter. The choice is, although, based on that you could find a lot of western influences in the neighborhood that could be redesigned into more sustainable solutions, such as poor established lawns, bare ground, hard paving, water features that don't handle storm water etc. There are also places for social activities within the neighborhood.

Neighborhood introduction

Rongcheng is a relatively newly built neighborhood, located south of Bell Tower outside the City Wall, close to Xi'an University of Science and Technology. Compared to the surroundings, the neighborhood contains a lot of greenery. There are no public park within 300 m and the closest public park is 0,7 km away. Numerous people circulate within the area and there are friends and other people from other neighborhoods visiting the unit as well. A lot of families are living in the neighborhood.

The neighborhood has a lot of flowering trees and shrubs, one big artificial water pond with a meandering canal that flows through the central area of the neighborhood, giving shape to a big island. There are also an outdoor gym, a basketball plan, table tennis, a playground for younger children and lots of benches. The parking lot is located underneath the yard. A few parking lots are placed on the yard though, but they are not used as parking lots. People use them for sitting,

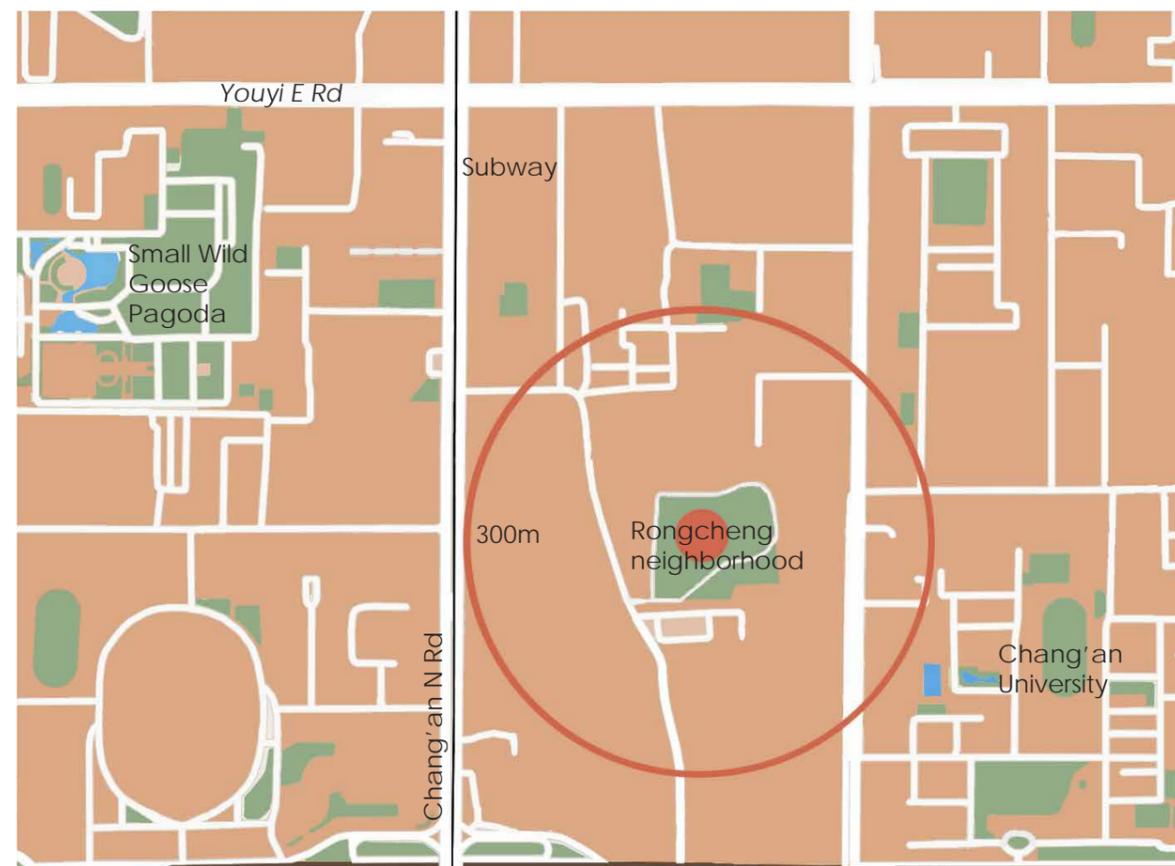
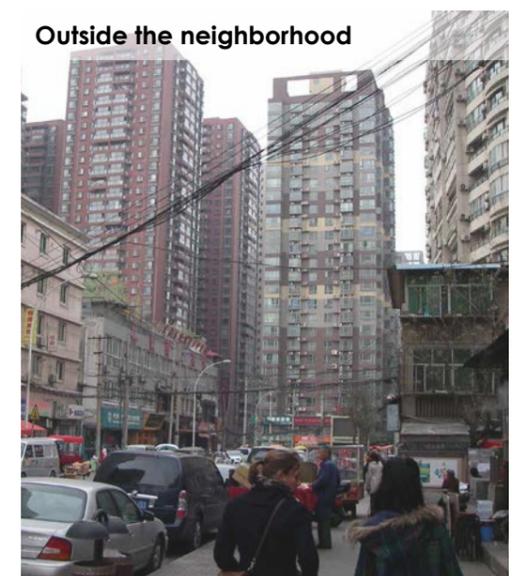
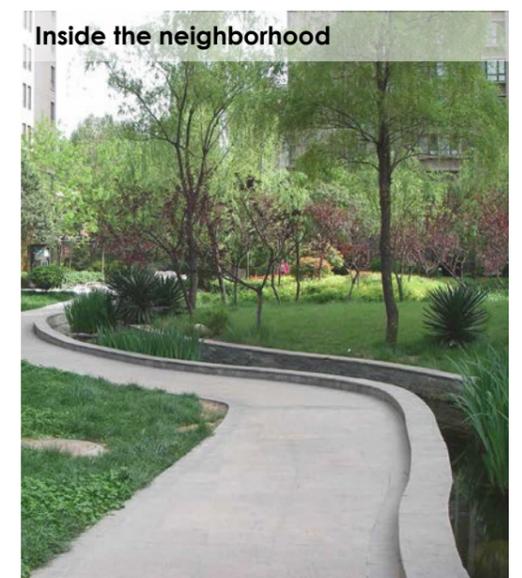


Figure 14. Shows a zoomed map of the neighborhood location and the nearest public parks. The orange circle indicates a radius of 300 meters.



playing and to dry their laundry. As a result of that, the residential yard is pretty much free from cars. People are very happy about the great amount of green areas and all the blossom in the neighborhood.

Local conditions and structure

Nine very high independent buildings in the neighborhood embrace one bigger central area. The buildings are oriented by a north-south direction. Façades are made of brick with a warm beige/brown polish. One bigger asphalt road runs in the outskirts of the area and several smaller hard paved pedestrian paths link the different buildings to the central core of the neighborhood. Due to the high buildings, different parts of the yard are shady depending of the time during the day. At our observational sites 1, 2 and 3, both sun and shadow from buildings are present depending of time of the day.

Facts
 Name of the unit: **Rongcheng**
 Located in: **Caochangpo, Xi'an, Shaanxi, China**
 Built in: **2008-2010**
 Areal: **About 80 000 m²**
 Number of buildings: **9**
 Number of floors: **26 floors except from one lower building with 8 floors**
 Car park: **Underneath the residential yard**
 Proportion of hard-surface in relation to green surface: **40 % hard-surface, 60 % green surface**

-  Green areas
-  Buildings
-  Hard paved areas
-  Parking lots
-  Water
-  Stepping stones

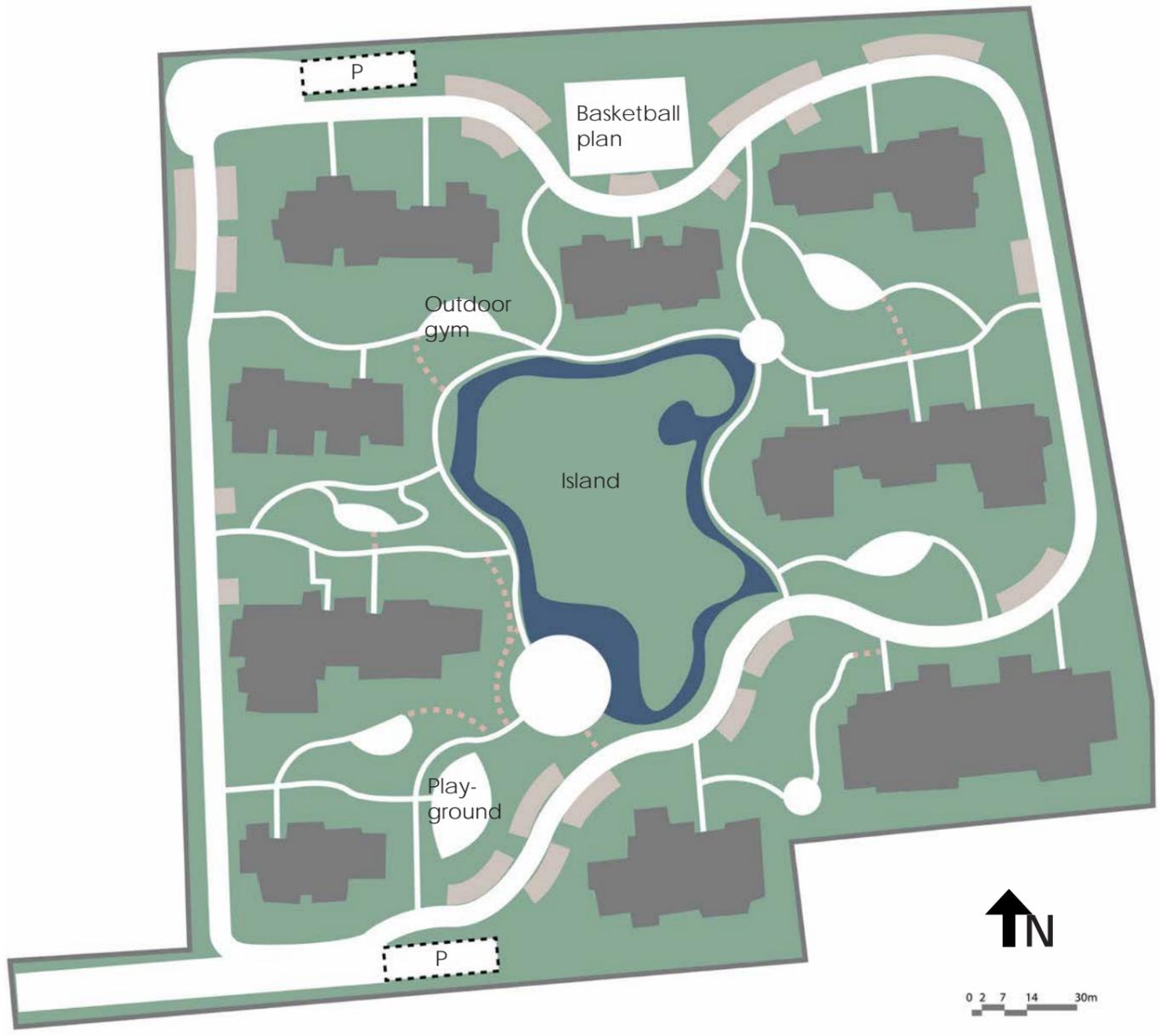
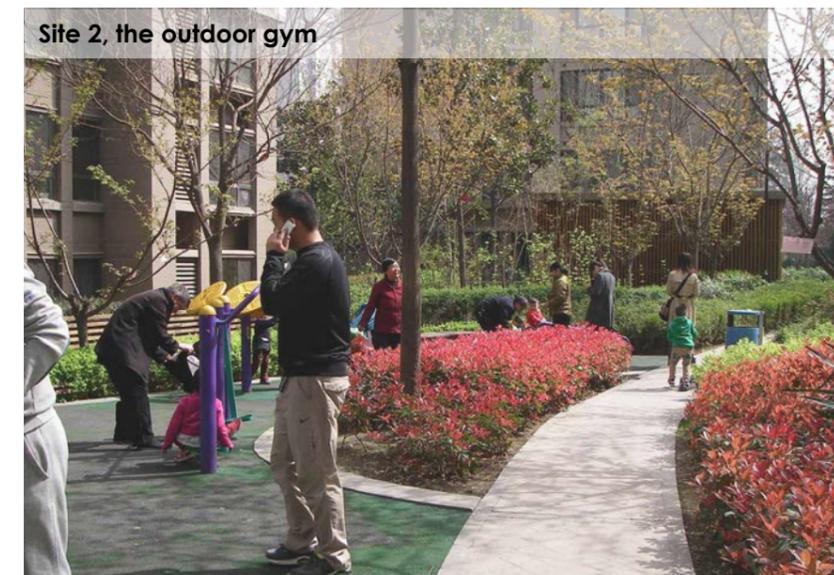
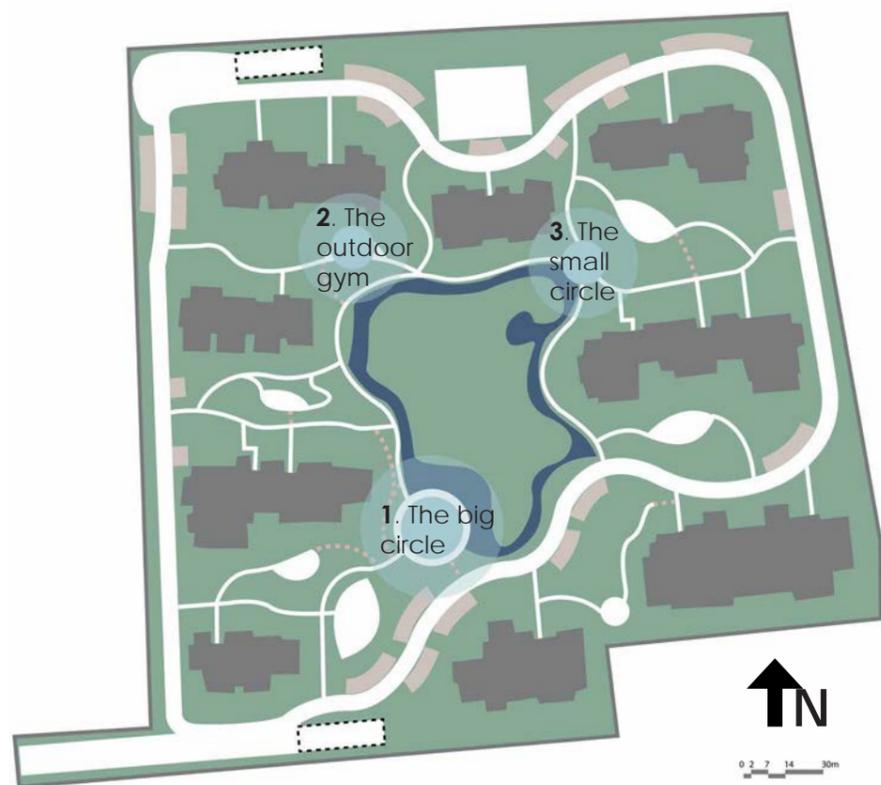


Figure 15. Displays present features of Rongcheng neighborhood.

Figure 16. Displays the location of the three observational sites.



Plant material

There are a lot of different trees and shrubs in the area, both evergreen, conifer and deciduous species. See table 8. Especially a lot of blossom trees are present, such as *Prunus persica*, *Magnolia ssp.* and *Cercis chinensis*, which is beneficial for pollinators. Both trees and shrubs are very colorful. However, there were no intense fragrances.

Shrubs are mostly planted in big contiguous amounts, where different species are combined together creating contrasting colorful units. Trees are mostly planted in these shrub units. But there are also solitary trees and bigger shrubs planted in the lawns. Perennial groundcover is poorly present though. Only a few different species, such as *Oxalis corymbosa* and *Ophiopogon japonica* were discovered and there is a lot of bare ground to be found. Areas with open bare ground show that the soil type is clay.

Perennials and climbers can also be found on the roof top of ventilation buildings. In the pond grow *Iris*, *Juncus*, reed and water lily. On the island you can also find some *Hosta*. No annuals were found.

There are also a great amount of lawns in the area, a typical western influence. You can find four different types of grass lawns: one big open lawn area on the island, smaller lawn areas in front of entrances to the buildings, paths of lawns in combination with stepping stones and approximately everywhere in the neighborhood you can find narrow segments or strips of lawns, especially alongside pedestrian paths. In some spots, clover, *Trifolium pratense*, has spread into the grass lawn. Clover is a good contributor to enhanced biodiversity (Ignatieva³).

Table 8. List of plant species in the neighborhood.

| Trees | |
|-------------------------|-----------------------|
| Acer palmatum | Picea ssp. |
| Acer ssp. | Pinus bungeana |
| Aesculus chinensis | Pinus tabulaeformis |
| Cedrus deodara | Prunus cerasifera |
| Cercis chinensis | Prunus cerasus |
| Eriobotrya japonica | Prunus mume |
| Eucommia ulmoides | Prunus persica |
| Gingko biloba | Prunus ssp. |
| Gleditsia chinensis | Pyrus ssp. |
| Koelreuteria paniculata | Rhus ssp. |
| Ligustrum lucidum | Robinia psuedoacacia |
| Liniidendron chinensis | Salix ssp. |
| Magnolia grandiflora | Sophora japonica |
| Magnolia spp. | Trachycarpus fortunei |
| Malus spectabilis | |

| Shrubs | |
|---------------------------------------|------------------------|
| Amygdalu triloba | Phyllostachys viridis |
| Berberis thunbergii var. atropurpurea | Physiocarpus ssp. |
| Buxus sinica | Pittosporum tobira |
| Cornus alba | Pladycladus orientalis |
| Euonymus japonicus | Punica granatum |
| Euonymus kiautschovicus | Pyracantha fortuneana |
| Forsythia suspensa | Rosa ssp. |
| Ligustrum sinense | Sorbaria sorbifolia |
| Ligustrum vicaryi | Spiraea salicifolia |
| Lonicera nitida | Spiraea ssp. |

| Shrubs | |
|---------------------|------------------------|
| Mahonia bealei | Syringa ssp. |
| Nandina cosmetica | Thuja ssp. |
| Osmanthus fragrans | Viburnum odoratissimum |
| Parthenocissus ssp. | Weigela florida |
| Photinia serrulata | Yucca gloriosa |
| Photinia x fraseri | |

| Perennials | |
|------------------|---------------------|
| Duchesnea indica | Ophiopogon japonica |
| Hosta ssp. | Oxalis corymbosa |
| Libertia | |

| Water plants | |
|----------------|----------------------|
| Glyceria | Nymphaea ssp. |
| Iris ssp. | Phragmites australis |
| Juncus effusus | |



Observations

The result of the observational study showed that Chinese people don't use green spaces the same way as we do in Sweden (for example, using lawns for picnic and sunbathing). In fact Chinese people don't use their lawns at all. There are signs in the neighborhood telling you that it is forbidden to walk on the lawns and a guard watching to make sure no one breaks the plant material. There are also stepping stones in the lawns where you are supposed to walk. Still there are, of course, people crossing the lawns sometimes, using it as a shortcut. The corners of the lawn are where you found most wear from shortcuts and open bare ground due to the wear. The lawns are in general poorly established. Trees and shrubs are in good condition, but the water quality in the pond is poor and it seems like there is poor or no circulation at all. There are some fish living in the pond though, but they don't seem very well.

The observations also showed that no one is using the island in the pond. It is a little tricky to get there (you must step on rocks in the water) and the majority of the island is covered by one huge lawn.

You can find open bare ground in some of the shrub areas, especially close to the playground, but we never saw anyone go there. Not once. Our perception is that people walk, sit, and play etc. where they are "supposed" to do it. People walk on hard paved paths and stepping stones, play in the playground, sit on the benches, exercise in the outdoor gym etc. People use all surfaces that are not green. If they step on the green areas, it is mostly to get a close look at a flowering tree and take a picture of it. According to our perception, green areas within the neighborhood have a high aesthetic value with mainly recreational purposes rather than playing, sitting, walking and other different activity purposes.

The most common things Chinese people do in their neighborhood

is walking, sitting, talking, playing and exercising. In the mornings you can find people dancing. But not as much dancing people as you can find in public parks. And if you have a dog, it is common to walk the dog in the neighborhood. The result was the same for every observational occasion. What differs is the amount of people outside. Most activity you find on weekends with sunny weather and the lowest activity you find on weekdays with bad weather. The area is most visited by children and their grandparents. Especially in weekdays, grandparents take their grandchildren for a walk with the baby stroller, showing them flowers or taking them to the playground. According to our perception the playground was intensively used no matter if it was morning, afternoon or evening.

One could actually hear a lot of sounds in the neighborhood. Both noises from traffic, constructions and celebration gunshots and sounds from bird singing, people talking, children playing and music was occurring.



Reflections

There are a lot of people walking in the neighborhood, both in weekdays and weekends. Especially in evenings, people like to go for a walk in the neighborhood after dinner. People also use the outdoor gym a lot more than people do in Sweden. And when the playground was too crowded, children played with the outdoor gym equipment. They did not play much inside the plantation which is very different from Sweden, where children often use plantations as their play areas.

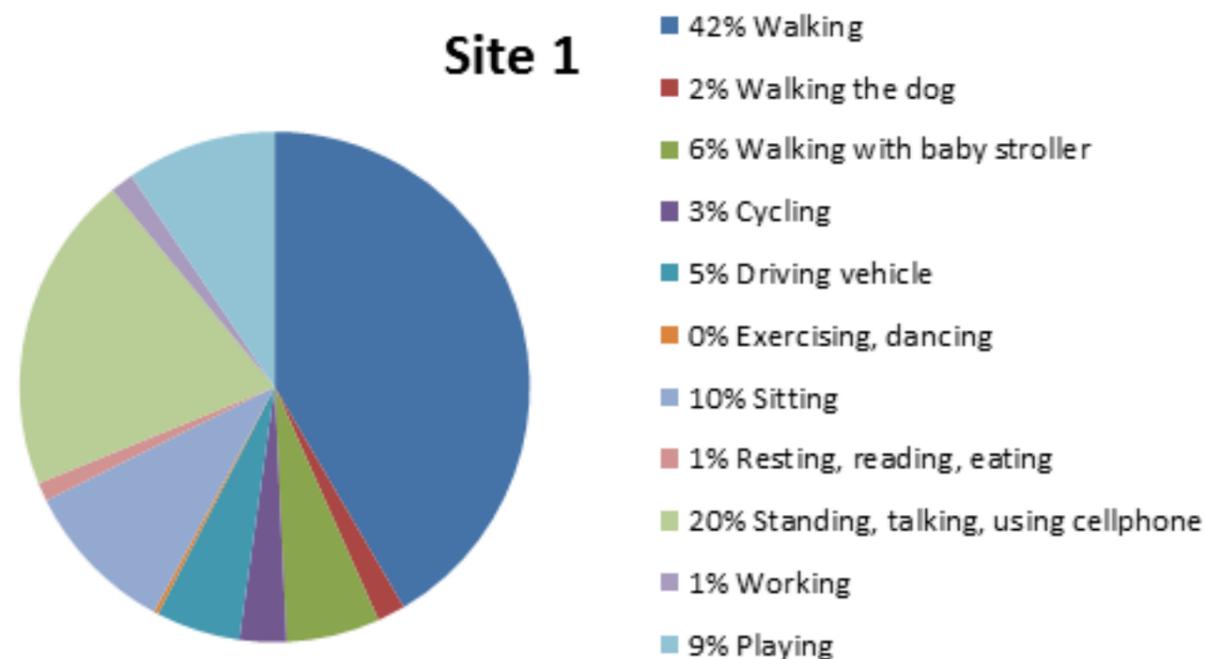
People also prefer to sit, stand, play, exercise etc. in the sun. It was very obvious that people moved along with the sun. As far as we know, though, it should be the opposite way during summertime due to very hot summer days in Xi'an, when you probably find it more convenient to sit in the shadow.

Site 1, the big circle, was however the most visited spot (besides from the playground) in the neighborhood. People really liked to spend time there. In general there was a lot of noise in the neighborhood, mostly from children playing, but also from traffic and people conversations.

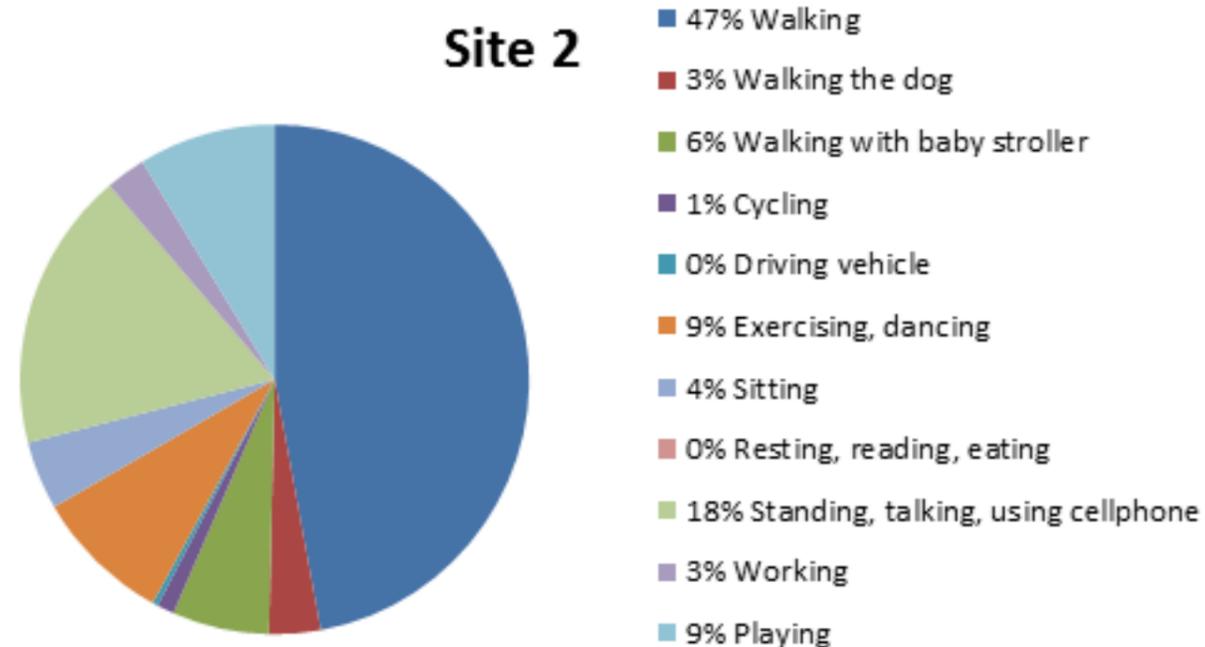
The presence of guards in the neighborhood might be a result of why people don't use the green spaces. There are security cameras in the neighborhood as well that may be the cause.

Figure 17. Pie chart of people activity (A, B, C, D) indicates the percentage of different people activities in the neighborhood, both necessary activities, optional activities and social activities, for each site as well as total. -->

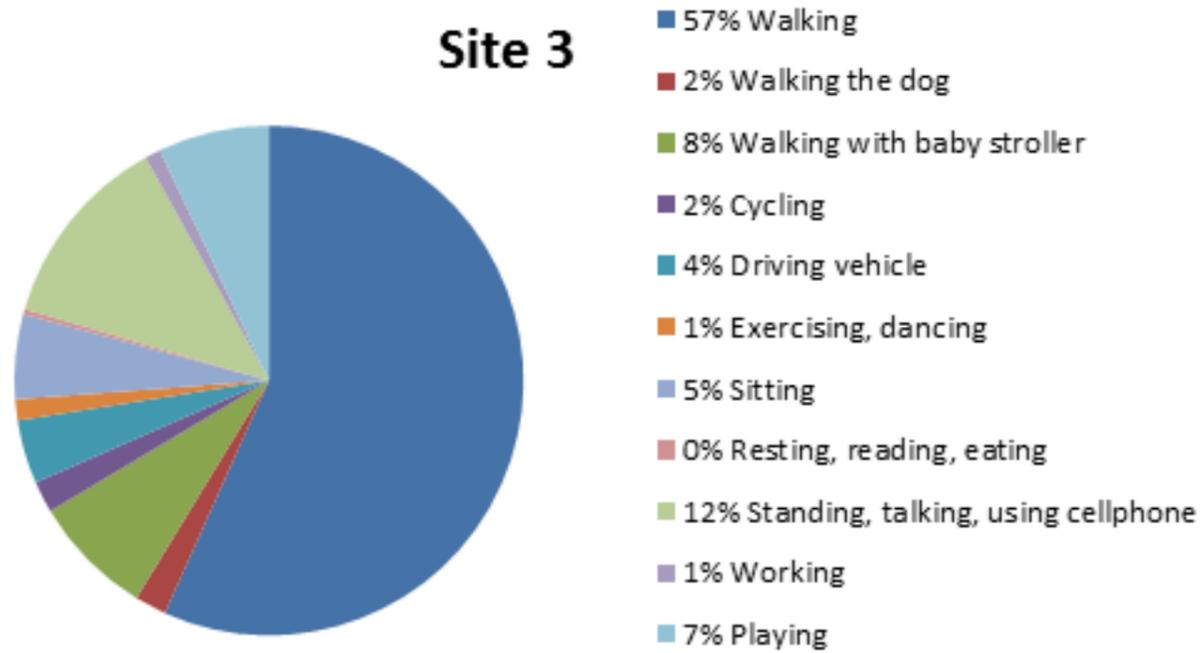
A) Pie chart for Site 1.



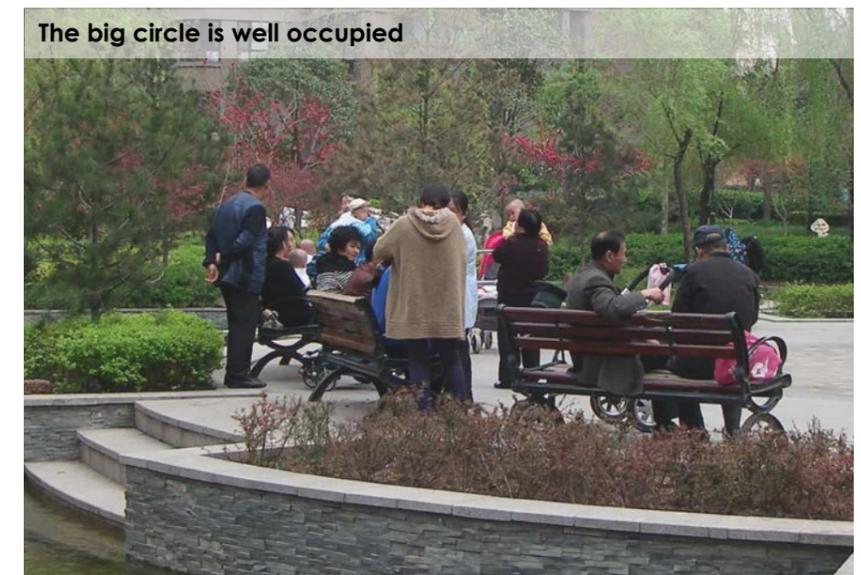
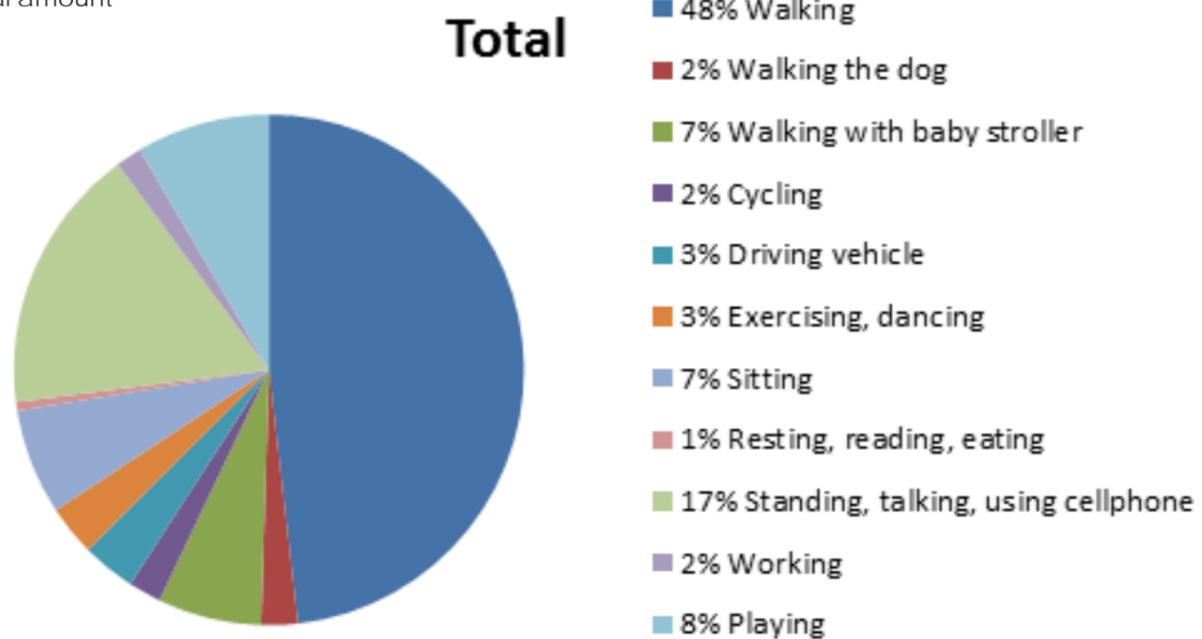
B) Pie chart for Site 2.



C) Pie chart for Site 3.
57% just walking by.



D) Pie chart of the total amount
of people activity.



ANALYSIS

SWOT – Intermediate Scale

Table 9. Displays strengths, opportunities, weaknesses and threats regarding the environmental conditions in Rongcheng.

| | |
|---|---|
| <p>Strengths</p> <ul style="list-style-type: none"> A lot of green spaces Space between buildings --> sun to the area The area is used by people - A lot of people using the area The parking lots are underground Green roofs on the ventilation buildings Many blossom trees --> positive for the insects Big variation of different species of trees and shrubs Places for social activities Bird song Water features | <p>Weaknesses</p> <ul style="list-style-type: none"> Boring entrances to the buildings open bare ground High buildings --> shady Many pruned bushes Small number of ground cover plants Poor circulation in the water Eco within the neighborhood from all the noise Poorly established lawns Inconvenient waste disposal Not much luminaries during the dark hours You can hear the traffic Too high buildings and no space because of the many windows for building green walls |
| <p>Opportunities</p> <ul style="list-style-type: none"> The parking lots within the area are not used anymore Lawns could be transformed into biodiversity meadows Hard paving could be turned into more permeable surfaces The water features could be transformed into storm water managements Enough space to implement bio swales and rain gardens Build sedum roofs on the high buildings Plant more ground covered plants Make a better way for waste disposal | <p>Threats</p> <ul style="list-style-type: none"> A lot of people using the area --> increased wear Shadow from buildings --> hard for plants to get established Not many green spaces in the surrounding area --> bad for the biodiversity and the overall ecosystem in the city |

Lynch - Intermediate Scale

Landmarks: The big circle, the island and pond, basketball court.

We consider the big circle as the most popular landmark in the neighborhood. It serves as the neighborhood core, easy to recognize due to the shape of it and the pergola. There you can find a lot of people from all ages, playing, talking, resting and sitting. Adjacent to the big circle is the water feature, the big pond, with its island. The island is a good site for orienting yourself because it is visible from all sites. There is one basketball court in the area where you can also play badminton and table tennis. It is a well known place visited by both older and younger people. The big circle is considered as both landmark and node.

Nodes: The big circle, the playground, the outdoor gym.

The three spotted places are nodes where a lot of people prefer to dwell and meet in the neighborhood. The places are very popular and used regularly. The big circle and the playground are rarely empty. Pedestrian paths pass through the sites, hence, a lot of people are also passing through. Except from exercising, you can also find people playing and resting in the outdoor gym.

Barriers: The wall/fence enclosing the neighborhood, the water feature.

The neighborhood is a gated community. There is a wall enclosing the whole area with security cameras. Due to the wall there is only one way in and out in the neighborhood, hence, the wall creates a barrier for pedestrians, vehicles and animals. The water feature is also a barrier. There are no bridges to the island and because of that it is difficult to cross both the pond and the island since the water is quite deep.

Paths: The bigger road, pedestrian paths.

The bigger road goes through the outskirts of the area. Here you can find cars and other vehicles passing, but it is also a popular pedestrian path. Throughout the neighborhood are smaller paved paths where most pedestrian activity is taking place. Most activity you find in the center zone. The wider line in the map, the more activity.

Districts: Center zone, local residence environment zone, road zone, entrance zone.

The different districts are divided according to our perception of them having a similar character. The center zone creates the core zone in the neighborhood. There, most activity is taking place and you also find most of the ornamental features such as water, lawns and flowering trees and shrubs. The character in the local residence environment zone is more intimate, still with a lot of trees and shrubs, and you can find a secluded quieter spot to sit down and have a rest. The road zone contains, besides the bigger road itself, empty parking lots, the basketball court, the waste collection area and the vegetation adjacent to the road. At last is the entrance zone. It has got more of a public character with small grocery stores and a kinder garden. There is also a map of the neighborhood and, of course, you find the big gate to the neighborhood with appurtenant guard as for many other neighborhoods in Xi'an.

-  Landmarks
-  Nodes
-  Barriers
-  Paths
-  Districts

Figure 18. Displays the Lynch analysis of the neighborhood.



PROPOSAL/GUIDELINES INTERMEDIATE SCALE

 New sustainable proposal/idea

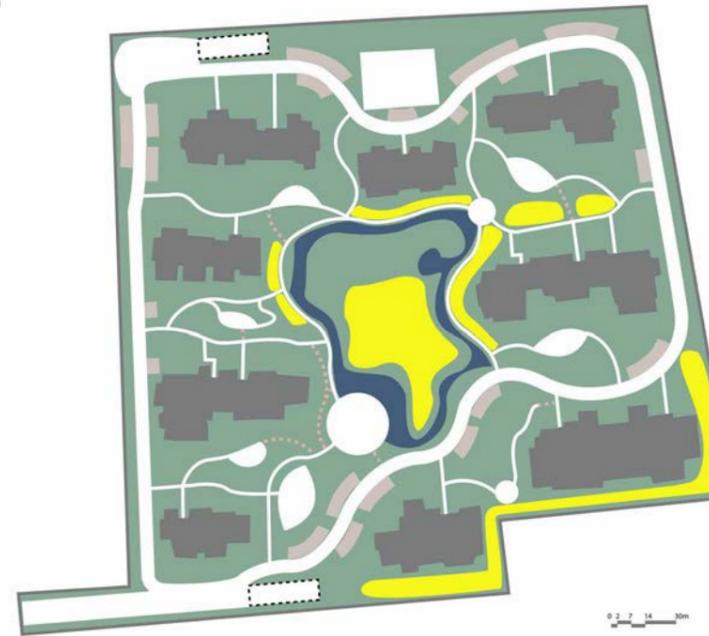
Our proposal aims to develop various ecologically sustainable design solutions for different spaces in the Rongsheng neighborhood. Due to poorly adapted western influences and high maintenance of lawns for example, other solutions are preferred. First presents a guideline for Rongcheng neighborhood in particular and then follows ecological guidelines applicable to other similar neighborhoods.

Rongcheng

Below displays the full proposal for Rongcheng neighborhood, but further on, every guideline is explained in detail one by one. The actual surface is yellow.



A)



B)



Large, continuous open lawns

These areas are suitable to be transformed into areas with native ground cover species, for example *Trifolium pratense*, *Ophiopogon japonica* and *Duchesnea indica*. The large lawns are poor and require a lot of maintenance. Different ground covers benefit biodiversity and would not obscure the view within the neighborhood. In some places it could also be convenient to plant coherent areas of low shrubs. Both solutions will lower the costs and fumes from regularly mowing.

Grass lawn that can be changed to low ground covers



Broad grass stripes

In some places in the neighborhood there are broad grass stripes along the paths. Bio swales with native plants could be an alternative to the poor grass surface.

Broad grass stripe suitable as a bio swale

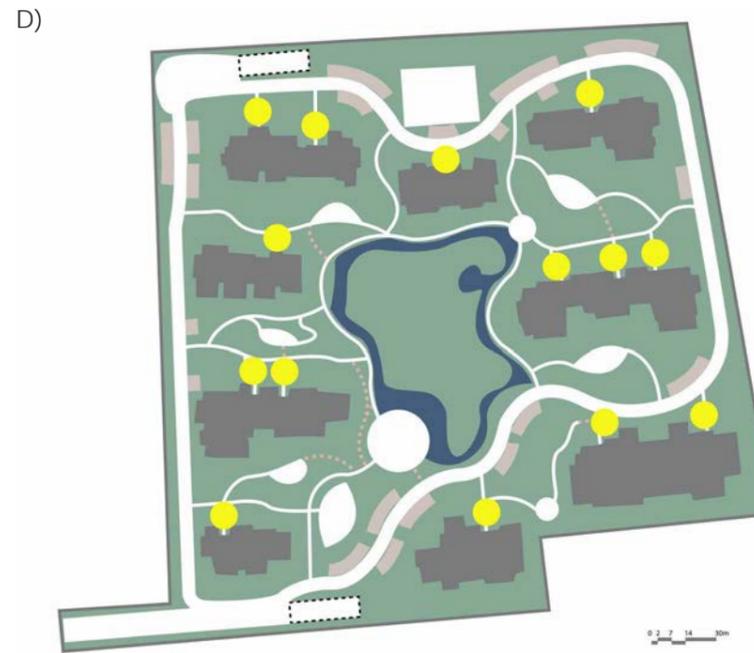


Figure 19. Schedule of fully proposal and ideas for Rongcheng. A-Q displays them more in detail.



Narrow grass stripes

These surfaces are often found along the paths and pose no function with its poor grass. To plant ground covering plants or shrubs instead are more convenient.



Entrances

The entrance areas to the residential buildings are poor, both in terms of aesthetical and ecological values. Some of the areas outside the entrances are suitable to redo into rain gardens, often there are low points with poor lawns which are worn. Outside the other entrances, often higher located, there are smaller grass surfaces where more flowering shrubs and ground covering plants could be plant instead. As for all entrances, they could be more welcoming with a better design.



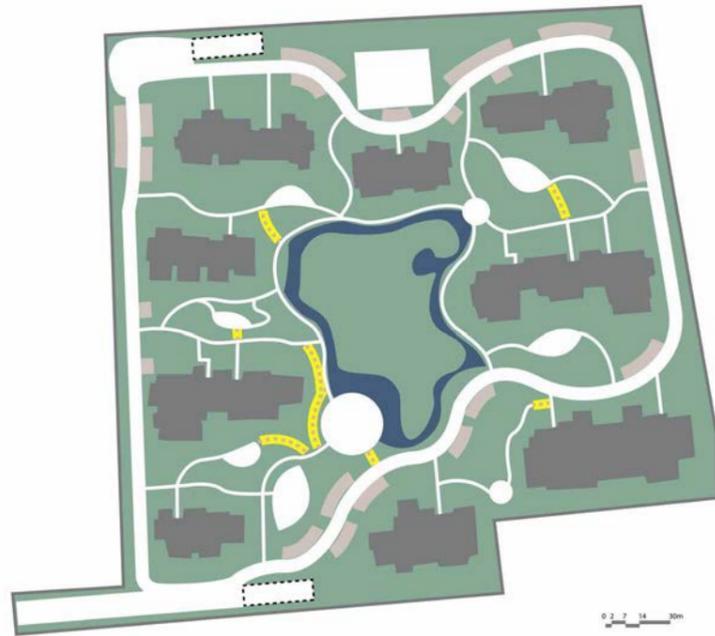
Grass under cluster of trees

Due to the shady surface under the trees the grass are very poor. Shrubs and ground covering plants are a better alternative to make the surface more ecologically sustainable. It is also more related to the traditional Chinese classical garden model (Ignatieva³).



³ Maria Ignatieva, Professor in Landscape Architecture, Swedish University of Agriculture Science, lecture 2015-04-22.

F)



Grass combined with steppingstones

Steppingstone paths through grass areas are recurrent in the neighborhood. The maintenance hampers and the grass are worn. This would be avoided and more sustainable with low ground covering plants, it will also get a connection to the traditional Chinese landscape.

G)



Bare ground under trees and shrubs

There are areas in some plantations where nothing is growing and the soil is visible. To make it better in an ecological way and for the aesthetical value in a traditional way, ground covering plants and shrubs should be plant in those areas.

H)



Water features

The pond in Rongsheng could be transformed into a storm water pond, where storm water from the surrounding paths and other surfaces could be collected. Also to improve the water condition a circulation in the water should occur, a fountain or a small waterfall where there are differences in height for example.





Parking lots

The parking lots within the neighborhood are not used by cars. Some of them are used for activities like ping pong and there are sitting occurring too. People also use these spaces to hang up their sheets for aeration. There are big opportunities to make these places more ecological oriented. Rain gardens with space for social activities in some of them would be a good alternative. This idea is further developed in the Small scale chapter.



Large road with speed bumps

To take care of the storm water from the large road in the neighborhood, speed bumps in the form of rain gardens would be a good solution. This is also a more aesthetical way to build speed bumps than the ones that are there today.



Plantations with edge support along the large road

Another way to take care of the storm water from the large road in a more ecological way could be to make an opening in the edge support so the water can infiltrate in the plantations.



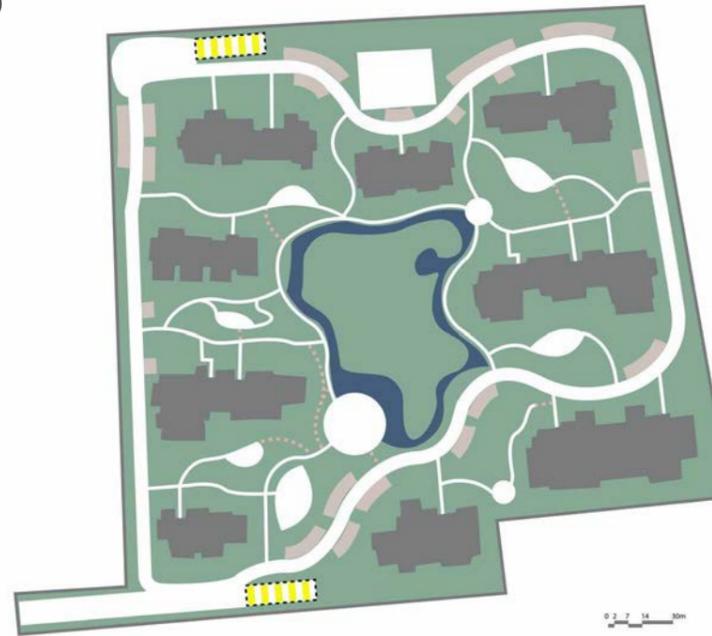
L)



Roofs of residential buildings

To use the roofs as planting beds is a smart way to apply more greenery in cities we think. Therefore, green roofs in the neighborhood could be implemented, using for example *Sedum*. The excess water could be led to the downpipes.

M)



Garage entrance roofs

Within the neighborhood there are a couple of garage entrances. On top of those green roofs could be applied or climbers could be planted to cover the surface.

N)



Downpipes

Today the downpipes from the roofs are emptied into wells on the ground. A better way to take care of the water and make it more ecological advantageously is to lead the water to the plantations instead.

Roof tops can be planted with *Sedum*



Garage roofs can become green roofs



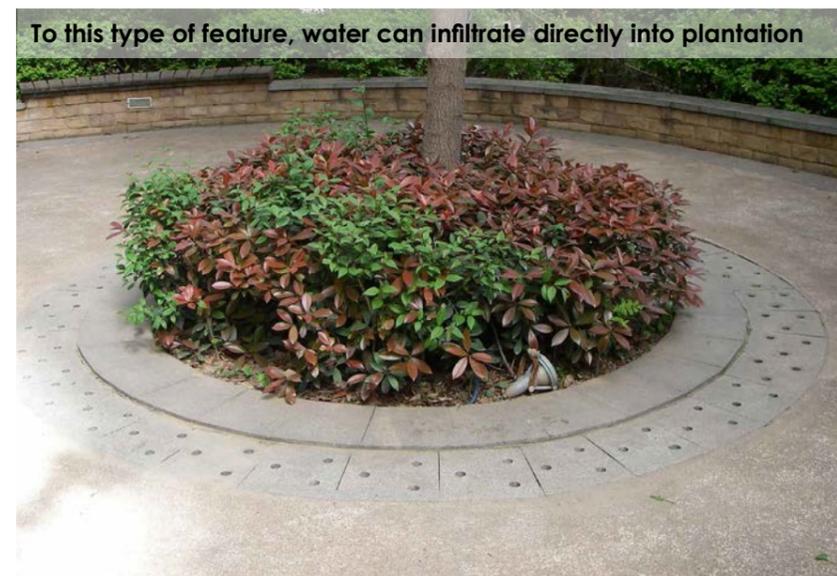
Downpipes can be led to plantations instead of wells





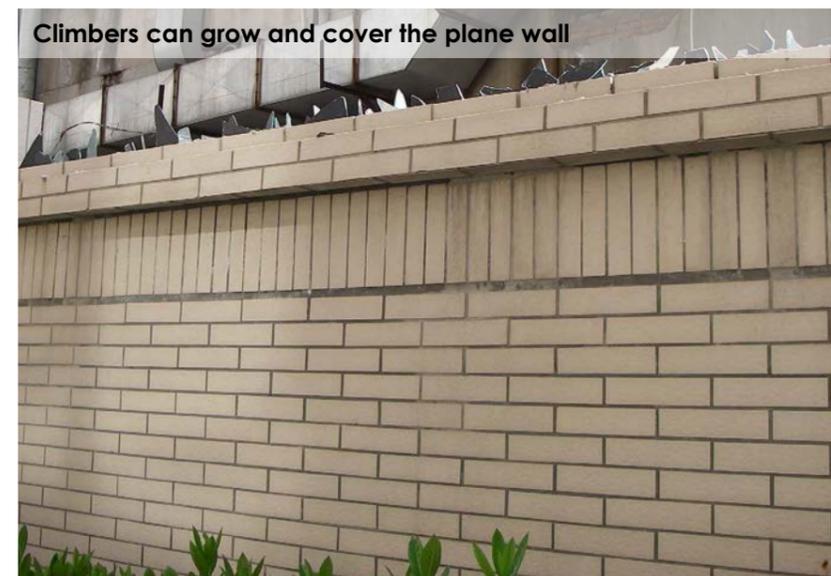
Plantations surrounded by storm water drain

In some yards between the buildings there are plantations surrounded by hard paving. In the hard paving around the plantations there are storm water drains. These could be transformed into rain garden plantations instead, to take care of the storm water locally on spot.



Wall surrounding the neighborhood

There is a plane wall with barbed wire on top which is surrounding the entire neighborhood. This surface could be used to increase the greenery in the neighborhood by letting climbers grow and cover the wall.



Garbage corner

In the North West corner there is a collection for garbage. There are some garbage cans but also waste lying on the ground in piles. The waste management could be improved both for the environmental aspect and for the aesthetic aspect. By building a special house for waste management these aspects could be improved. A green roof on top could also be implemented.



Applicable to other neighborhoods/cities

Here presents a list of general guidelines for applying sustainable ecological design solutions to other neighborhoods and cities in China, based on the common elements and characters we found in other neighborhoods in Xi'an. The guidelines aim to enhance biodiversity and urban wildlife habitat conditions, incorporate natural drainage system for sustainable treatment of storm water, increase the aesthetic values, enhance knowledge of the natural system and facilitate maintenance.

Large, continuous open lawns

Areas of this character could be replanted with different types of low ground cover. For example, native ground covering species, such as *Trifolium pratense*, *Trifolium repens*, *Ophiopogon japonica* and *Duchesnea indica* (Ignatieva³). This would increase the species richness, hence, benefit biodiversity and lower the costs and fumes from regularly mowing. Turning grass lawns into ground cover areas would also make the green area more authentic to classical Chinese gardens.

Broad grass stripes

For strips of this character, bio swales with native plant species are a more sustainable design solution instead of just a plain section of lawn with high maintenance. The bio swale can take care of a bigger amount of storm water runoff and can also be vegetated by different flowering species that provide valuable food sources for urban wildlife.

Narrow grass stripes

Regarding fragments of this kind, where the grass is more or less just a border to the plantation, it is more convenient to plant these stripes with lower shrubs or ground cover species. That will lower the costs and fumes from regularly mowing.

Grass under cluster of trees and shrubs

Areas of this character are difficult to maintain due to both mowing



and trimming of the grass around freestanding trees and shrubs. Coherent areas of shrubs and ground covering plants underneath are a better alternative than lawn to make the surface more sustainable. It is also more authentic to classical Chinese gardens to use native ground cover species than grass.

Grass combined with steppingstones

Stepping stones in grass areas are commonly seen. The maintenance hampers and the grass are sometimes worn. A more sustainable solution is to replace the grass with low native ground covering plants. That will lower the costs and fumes from regularly tricky mowing. Replacing it with flowering ground cover would also provide valuable food sources for urban wildlife.

Bare ground under trees and shrubs

Regarding areas of bare ground under trees and shrubs, native ground

covering plants and shrubs allowing more shady conditions should be plant in those areas to mantle the open soil and prevent rain water runoff.

Water features

All kinds of water bodies can be turned into sustainable storm water management, where the water is collected, cleansed and detained. It can also provide an aquatic and terrestrial habitat, beneficial for the biodiversity.

Parking lots

Hard paved parking lots can get a more permeable surface, such as grass reinforcement, in which storm water can infiltrate and percolate, to implement a more sustainable approach for storm water treatment.

Larger roads with or without speed bumps

All kinds of bigger asphalt roads within neighborhoods can be redesigned with speed bumps in the form of rain gardens or curb extensions, which can take care of run-off water from the road. That is both more aesthetical and sustainable than just having asphalt and ordinary speed bumps.

Plantations with edge support along the large road

Another way to get a more sustainable approach for storm water treatment is to redesign the edge support of the plantations along roads with openings in the edge support that will allow storm water to infiltrate into the plantations.

Roofs of different buildings

Solid rooftops can be turned into green roofs for a more ecological approach, using native sun tolerant plants and sedum species, such as *Poa pratensis*. The excess water could be led to the downpipes.

Downpipes

Downpipes that lead the water directly to a dwell could be redesigned to downpipes with an outflow that leads the water to the plantations instead, for a more sustainable storm water treatment approach.

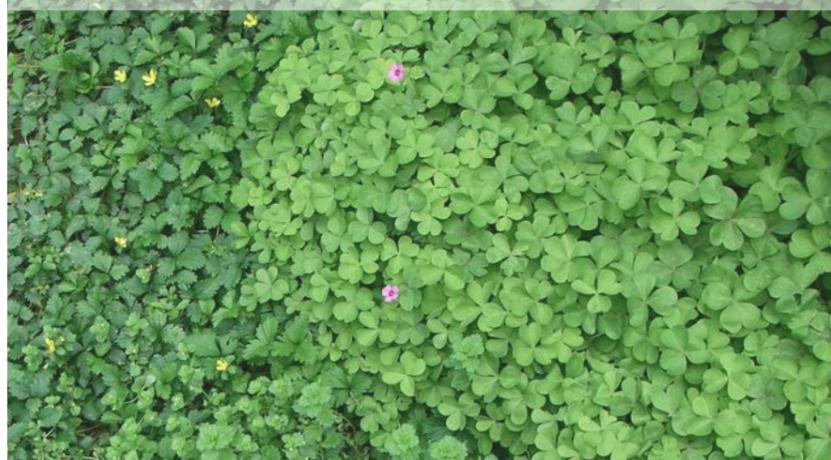
Wall surrounding neighborhood

Gated communities are commonly seen in Chinese cities, creating numerous meters of enclosing blank walls within the neighborhoods. These surfaces could be covered with climbers to enhance the greenery as well as ecological and aesthetic values in the neighborhoods.

Garbage corner

A proper functioning garbage disposal is something lacking in many of the neighborhoods. Waste is stored on the ground without a roof or anything that can prevent rain water from leaching dangerous substances to the groundwater. To avoid this, a special house for waste management should be built. To enhance the greenery and biodiversity in the neighborhoods, the building could be given a green roof as well.

Duchesnea indica and *Oxalis corymbosa*



Guidelines

Current appearance

- **Large, continuous open lawns**
- **Broad grass stripes**
- **Narrow grass stripes**
- **Entrances**
- **Grass under cluster of trees**
- **Grass combined with steppingstones**
- **Bare ground under trees and shrubs**
- **Water features**
- **Parking lots**
- **Large road with speed bumps**
- **Plantations with edge support along the large road**
- **Roofs of residential buildings**
- **Garage entrance roof**
- **Downpipes**
- **Plantations surrounded by storm water drain**
- **Wall surrounding the neighborhood**
- **Garbage corner**

Solutions

- Ground cover/low shrubs
- Bio swales
- Ground cover/shrubs
- Rain gardens/ground cover/shrubs
- Ground cover/shrubs
- Low ground cover
- Ground cover/shrubs
- Storm water pond
- Rain gardens
- Rain gardens
- Infiltration gaps in the edge support
- Green roof
- Green roof/climbers
- Lead water to plantations
- Rain gardens
- Climbers
- Waste management house with green roof

Trifolium repens as a ground cover



A good example of combined ground covers and shrubs





SMALL SCALE

This part shows a guideline for a small concrete design proposal in Rongcheng neighborhood. The proposal displays our vision of an ecological design solution of an abandoned parking lot area in the neighborhood.

PROPOSAL/GUIDELINES SMALL SCALE

The small scale approach further develop the intermediate scale idea for the empty parking lots in Rongcheng neighborhood. It aims to redesign them into social areas with an ecologically sustainable approach. There are several empty hard paved parking lots in the neighborhood and none of them are occupied by cars. Some of them have been in possession of the residents by laundry, table tennis and small tables and chairs. Our proposal shows how you can redesign 4 coherent parking lots in the neighborhood. Note that the proposal is meant to work as a guideline and that our intention is not to transform all of the empty parking lots into this concrete proposal.

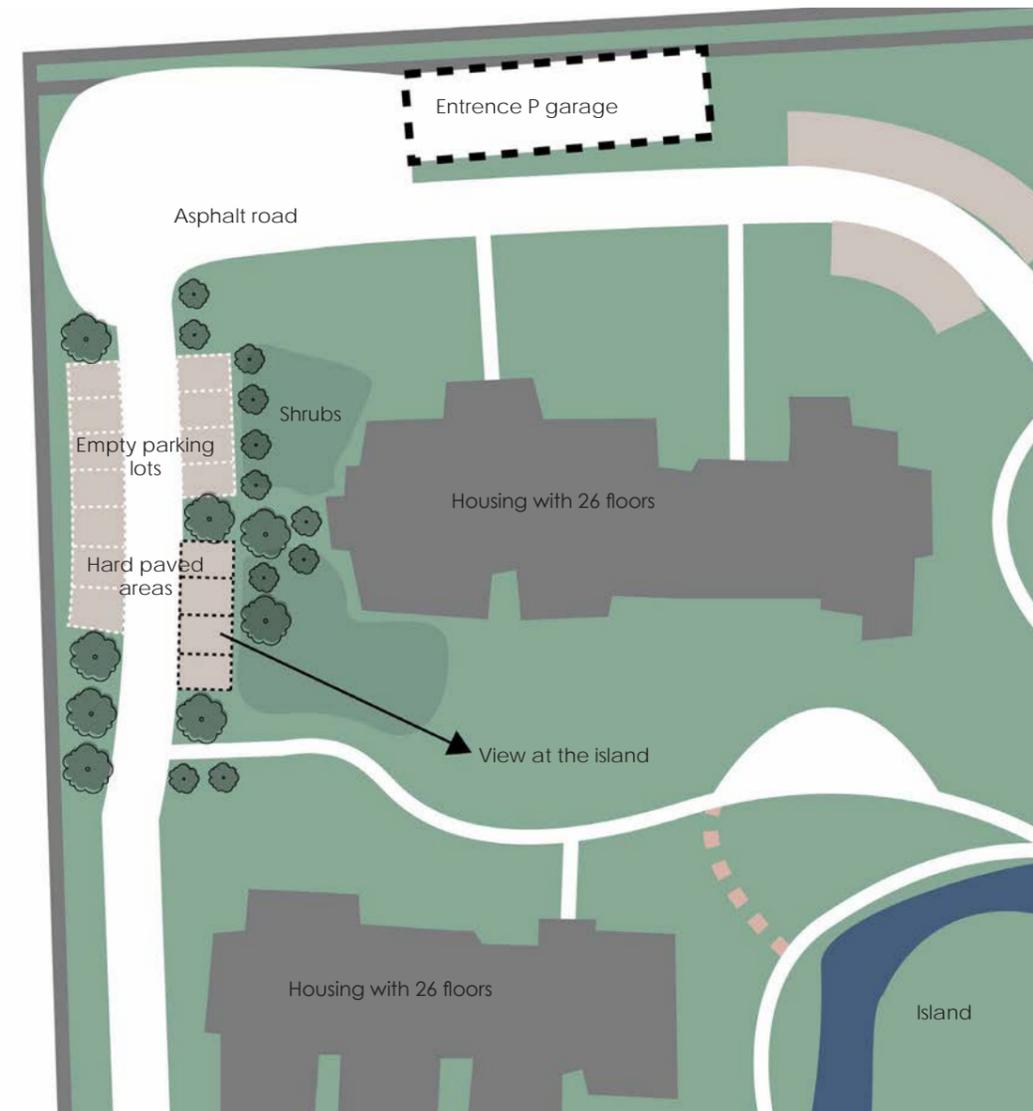
Inventory and analysis

For inventory and analysis in small scale proposal, the same data from intermediate scale is used and no further inventory and analysis is needed.

Today, the parking lots are hard paved surfaces, not used for their purpose. There is a big car park underneath the yard where all the residents park their cars, which makes the parking lots up on the yard, thus, to objects with great potential for redesigning into better purposes.

The parking lots are connected to the bigger asphalt road in the neighborhood on the west side. On the other three sides, the surface connects to the neighborhood vegetation. The 4 coherent parking lots create an area of 50m² (5 x 10m). See map of small scale. Our observation showed no activity on these 4 parking lots. The area is semi-shade and sheltered by trees. From the spot one can see into the central core yard of the neighborhood.

Figure 20. Illustrates a combined inventory and analysis map. The four parking lots are marked and dashed in black.



Idea

Our idea is to transform these 4 empty hard paved parking lots into a social area where you can sit, eat and hang out with your family and neighbors. The surface is also turned from hard paved to permeable, where storm water can infiltrate and plants can thrive. In other words, we create a rain garden combined with a place for social activities. It is a win-win situation for both social and ecological aspects. Rain gardens do not exist in Xi'an now according to Dr. Ji (2015), but it is something to strive for to apply in the city.

Concept

Our concept is the Social Rain Garden. It is based on the combination of both a rain garden and a social area. Of course the design also takes in the Chinese culture and classical elements as well as native species.

Figure 21. Concept figure. Turning a grey area into a green-blue social area.



Guidelines

- Decrease hard paved areas
- Increase permeable surfaces
- Increase the green area
- Inspiration from the culture
- Use native species
- Increase aesthetic values

- Shrubs
- Ground cover
- Storm water pond
- "Health stones"

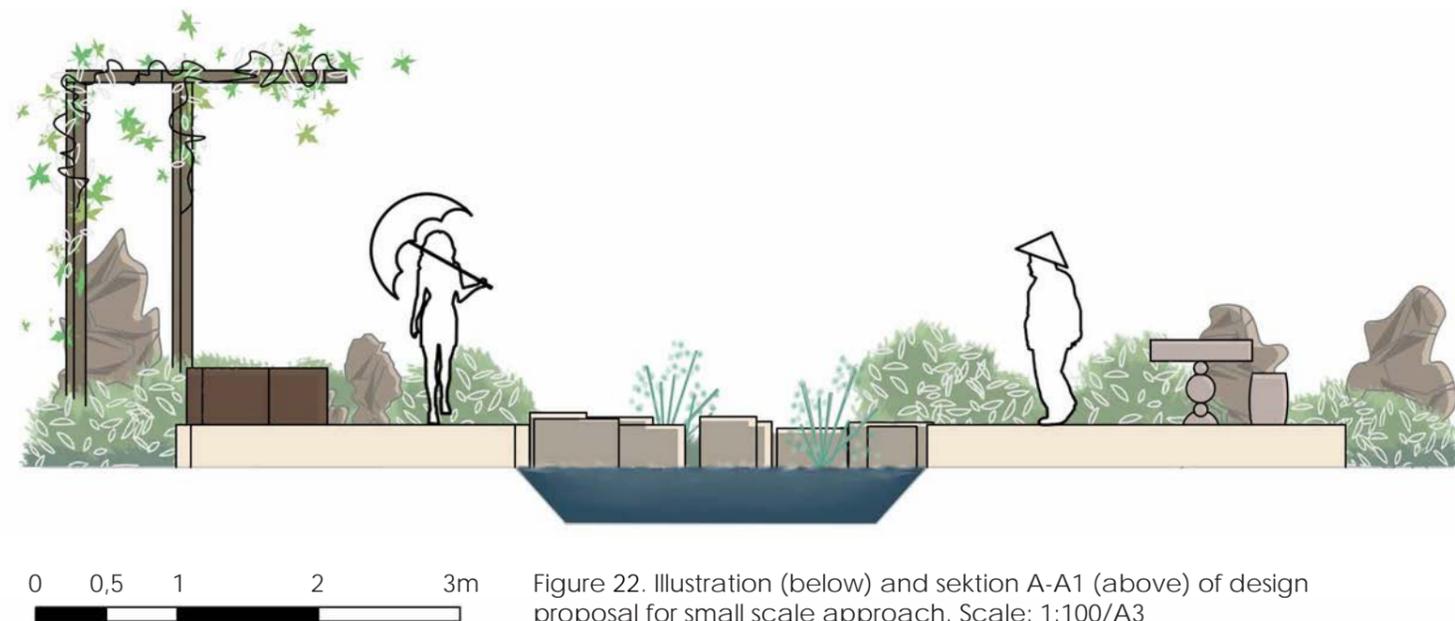
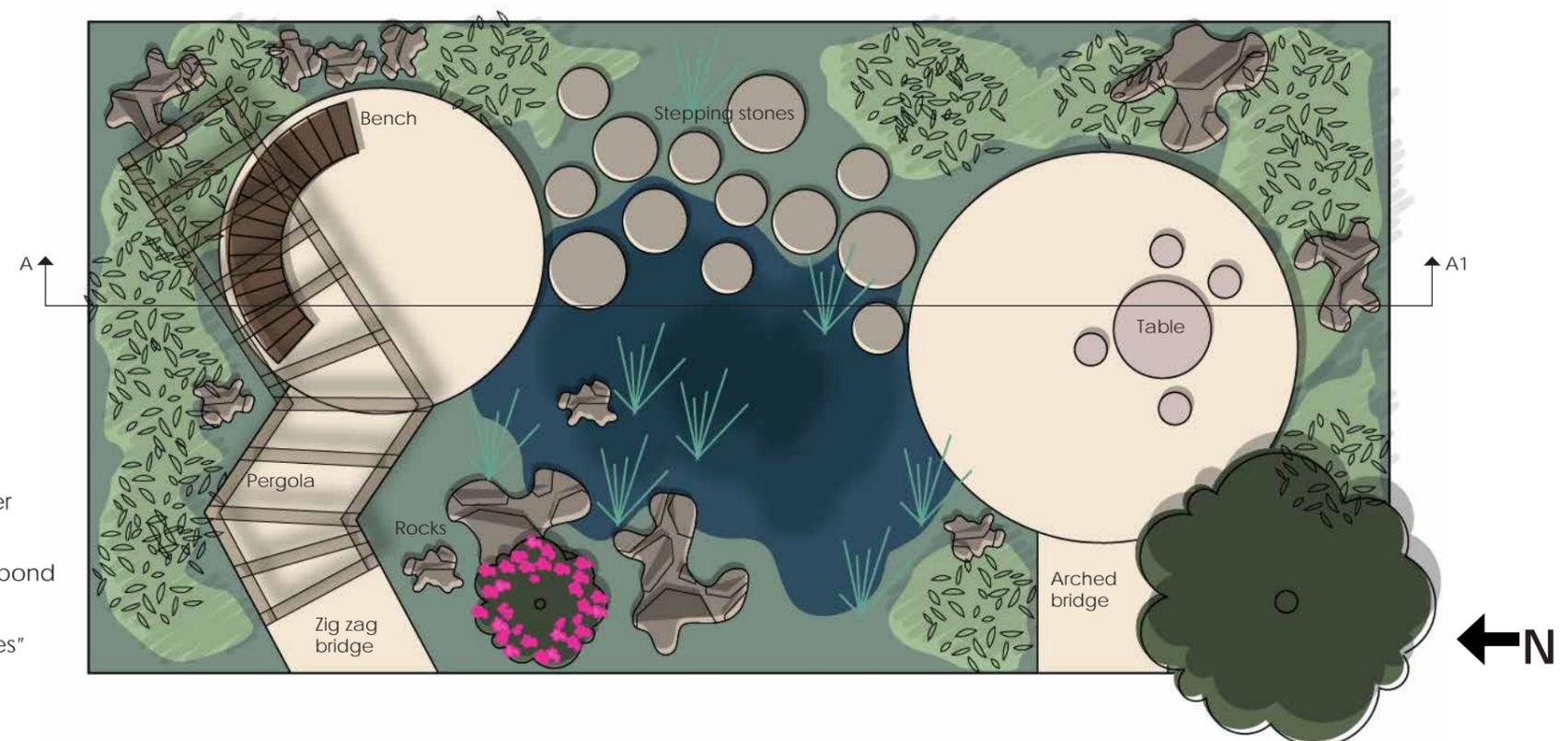


Figure 22. Illustration (below) and sektion A-A1 (above) of design proposal for small scale approach. Scale: 1:100/A3



Social Rain Garden

Our proposal contains two circles, inspired by yin and yang, where people can sit and socialize. Between the circles flows a strip of stepping stones in different sizes that connect the two big circles together. In the middle is a rain garden, which water pond content can fluctuate due to the amount of rain, creating an adventurous path via the steppingstones.

To get to the circles, one crosses the zigzag bridge with the pergola or take the small arched bridge. The pergola follows the shape of the zigzag bridge and creates some framed views along the way. One framed view is when watching through the pergola to the flowering shrub by the rocks. There are a lot of rocks in the proposal combined with native shrubs and ground covers to get an authentic feeling of a classical Chinese garden on the spot. The design and character is therefore simple, to be able to take in the spirits and souls of the uniquely shaped rocks and uncluttered views.

Shrubs, rocks, ground cover, trees and water create together a miniature landscape. It is like a small oasis of greenery. From one spot in the pergola, one can find a borrowed view of the big island in the center of the neighborhood. Both the bridges and circles are paved with health stones in different patterns, creating classical health stone paths in the neighborhood. The steppingstones are made of granite and the pergola is a wooden construction.

The plants in the rain garden should be resistant to both dry and wet conditions. The majority of plants should be native species. The character of the plant material also changes during the year. In spring, the focus is on the flowering shrub. In summer one can appreciate lush greenery and in autumn all shrubs turn into different colors showing an intensive color play. During winter the frost seizes hold of the swaying reeds, creating tranquil crystal whips.

Ecological approach

The redesigned area will collect, detain and clean the storm water run-off from the big road. A depress is created in the middle between the two circles. Rainy days, the hollow will turn into a pond and in sunny weather, the pond will dry out. The slopes of the depression will, hence, be covered with perennials that can survive in both wet and dry conditions, because of the fluctuating water level. For example *Juncus effusus* and *Lythrum salicaria* can be used in the depression.

By choosing native species, we can have a good establishment of the new plant material. In other words, the area does not require as much maintenance and will reach a stable plantation in short time, without a lot of bare ground for example. It will also require low maintenance because there are no lawns that need to be cut regularly and no shrubs that involve frequently pruning. The planting will adopt a wild character where plants can thrive and create an ecological dynamic. The biodiversity will be enhanced as well, by choosing different local species and flowering species that will become valuable food sources for urban wildlife.

Turning it into a rain garden will also increase the amount of green areas and decrease the hard paved surfaces in the neighborhood. And of course it will provide aesthetic values for those living in the area as well, which is beneficial for the mental health. Decreasing the hard paved areas and increasing the green ones, will likewise contribute to better air quality and decrease the temperature, hence, the island heat effect in the area.

Maintenance

Conventional design

- Regularly mowing
- Regularly pruning
- Unsure establishment of non-adapted global species
- Human-managed plant dynamic
- Stagnant water
- Impact on sewerage lines
- Irrigation

Ecological design

- No regularly mowing
- No regularly pruning
- Fast establishment with native species
- Ecological plant dynamic (more stable)
- Storm water drain
- No impact on sewerage
- Less irrigation



Recommended plant species

Listed below are species that are suitable for the rain garden. The list is a guideline with possible plant species to use. We do not recommend to put all of them into this small area.

Table 10. Presents examples of plant species possible to use in the Social Rain Garden.

| In the depression/pond | |
|------------------------|----------------------|
| Acorus calamus | Juncus effusus |
| Butomus umbellatus | Lythrum salicaria |
| Glyceria ssp. | Pontederia cordata |
| Iris wilsonii | Phragmites australis |

| Ground cover | |
|---------------------|--------------------------|
| Duchesnea indica | Orychophragmus violaceus |
| Glechoma longituba | Oxalis corymbosa |
| Imperata cylindrica | Trifolium pratense |
| Ophiopogon japonica | Trifolium repens |

| Shrubs | |
|--------------------|--------------------|
| Euonymus japonicus | Nandina domestica |
| Ligustrum vicaryi | Pittosporum tobira |

| Solitary trees and shrubs | |
|---------------------------|-------------------|
| Cercis chinensis | Prunus serrulata |
| Koelreuteria paniculata | Salix babylonica |
| Magnolia grandiflora | Wisteria sinensis |
| Prunus mume | |

Iris wilsonii in front and *Nandina domestica* in background



Phragmites australis



Ophiopogon japonica



Wisteria sinensis



DISCUSSION

手上留情花自香
脚下留意草如茵

If you don't pick the flowers they will smell well
If you don't walk on the grass it will be green

In this part, results and methods are discussed and evaluated together with our own reflections and suggesting further research questions.

DISCUSSION

The purpose of this master thesis was to study the green infrastructure in the Chinese metropolis Xi'an, in three different scales; from the overall city plan via intermediate neighborhood to the fine solution for a concrete design proposal of a specific site in the neighborhood. By doing interviews with professors, a local politician and a city gardener as well as field and observational studies, we have examined the questions:

- What are the main features of Xi'an green infrastructure?
- What ecological approaches can be applied to support a development of sustainable green infrastructure in Xi'an on different scales?

The results of this study could be used as tools or guidelines for suggesting sustainable green infrastructure development in Xi'an and other big cities in China. It could be a small step towards improving both living and environmental conditions in these metropolises.

Methodology discussion

Before the field study we tried to gather as much information as possible, because it was hard to predict the outcome of the trip. Especially because of the restrictions of using some internet applications in China such as Google, and access to electronic maps. With a steady pre-research, the work in Xi'an could start without impediment and proceed smoothly.

Our observational study took place during different occasions aiming to see how the neighborhood was used by the local people. We would like to get an even better understanding and could have done a more comprehensive study, like visiting the neighborhood in different seasons, but due to the limited time for our field study (only 8 weeks) it was not possible. However we got an adequate picture from the observational study to create a design proposal that would suit the

people and the neighborhood environment. What we don't know is if there are other aspects and findings that would have been discovered other times of the year which could influence on our design proposal.

During our interviews with the three professors from Northwest A&F University in China we got an insightful perspective of what they think of the green infrastructure in Xi'an. Interviews were also made with a local politician and a city gardener. The support from the interviews gave a greater reliability and validity to the results of our work. An interpreter was used during some of the interviews though, since they did not speak English. There is always a risk to use an interpreter due to the answers might not always achieve the exact translation and some loss of information may occur.

For the small scale design proposal in this thesis, the knowledge of the different features in the classical Chinese design was of great importance. The aim of our design was to make a proposal with an ecological approach, and at the same time to adjust it to the surroundings to be able to relate to the Chinese context.

In this sense we are seeing ourselves as two western persons that make an interpretation of the Chinese culture. We have looked at the parks with our western eyes and made a design proposal in small scale of how we understand the Chinese culture, based on our particular visits in Suzhou, Xi'an and Beijing as well as literature studies. Chinese person might have other opinions and addendums.

Our proposals in the three scales are meant to be used as guidelines for further development. If more time was set for this thesis, we could have done concrete design proposals for every scale.

Result discussion

The results from the inventory showed that the green infrastructure

in Xi'an is scattered. Public parks cover large areas but there are no connections (ecological network) between them. As Dr. Ling (interview 2015) mentioned, there is no network of green infrastructure because there is no concrete plan of how the green infrastructure of Xi'an should be developed. The present Green space planning map of Xi'an (p. 39) does not display the development of the green infrastructure in detail, neither provides any concrete guidelines. Both we and Dr. Ling (interview 2015) think that virtual mapping is a good way to start collecting required data for a detailed green space planning map.

Our classification of Xi'an GI further showed that there is different green infrastructure characters present in Xi'an with different values, which could be connected to each other. Our suggestion to link existing green areas by implementing green roofs, vertical gardens and expand the street greenery is one way. But of course, each linkage requires site specific solutions when it comes down to practical application.

Our observations showed that features of classical Chinese gardens still can be seen in modern green infrastructure in Xi'an. It is most presented in public parks where you could find these classical garden elements, such as rocks, water bodies, bridges, pavilions, framed and borrowed views. However the variety of details in pavilions and winding corridors as we found in Suzhou and Beijing Summer Palace for example, is not presented in modern parks. Maybe it is the details that put the finishing touch of spiritual fullness in Chinese gardens. As both Chen (2013) and Ignatieva et al. (2015) cited, Chinese gardens have nowadays lost their spiritual meaningfulness.

It is not only the details that are missing. Authentic materials are not used in modern parks anymore. For example rocks and caves are mostly made of concrete today instead of that carefully selected real stones that were presented in gardens of Suzhou. There is another modern Chinese phenomenon such as artificial trees in parks. Dr. Ling (interview 2015)

believes that it is a clear sign of greenery absence in public space. Plastic trees are not contributing to better air quality, so why put it there in the first place?

Colorful flowerbeds and tidy lawns are definitely western influences that are found in almost every modern park in Xi'an. These elements certainly are not belonging to the classical Chinese gardens. Ironically enough these Western symbols came even to classical gardens of Suzhou. Now in many historic gardens an additional part in Western gardenesque style is created aiming modern public satisfaction. Acceptance of Western model has become a status symbol of successful Chinese economy model (Ignatieva et al. 2015). The ongoing question is whether or not these western elements could be adapted to the local conditions and culture in China?

The result from the interviews clearly showed that China has similar goals and thoughts about the environment as we have here in Sweden. Chinese specialists and politicians are aware of that the green infrastructure needs to be improved and developed using more ecological sustainable methods. This pathway will help cities to counteract the bad air quality.

Dr. Ling's (interview 2015) vision to implement more lawns in urban environments in the future could be discussed. At the moment lawns in China require high maintenance (especially in hot Xi'an summers with tremendous irrigation input) and are not the best choice if you want to improve the ecological aspect (Ignatieva et al. 2015). As mentioned before, lawns in China are a quite new concept and not yet adjusted to the local conditions, hence, they require high maintenance to be kept in good condition. In the future though, the knowledge about lawns and its adaptation to local Chinese conditions might have increased and they could be maintained in a more efficient and sustainable way than today.

³ Maria Ignatieva, Professor in Landscape Architecture, Swedish University of Agriculture Science, lecture 2015-04-22.

As Dr. Ling (interview 2015) said, the focus on the natural resources in China is growing tendency. Before, the natural resources were set aside by the economic expansion. But now, with the steady economy, they have the opportunity to work on improvements of environmental conditions more seriously. The high CO₂-emissions in China affect the rest of the world as well. But as Professor Li (interview 2015) stated, the knowledge and awareness have to reach both the people and the government to get a full effect.

Li, Ling and Ji (interviews 2015) are agreed on that green walls and green roofs are the way to increase the greenery in Xi'an because of the lack of space for green areas in the existing city. We are talking about densify cities these days, so why not densify the green infrastructure at the same time?

Chinese specialists also mentioned that designers need more knowledge and more time in the projects to plan for ecological green spaces. It might take a while until China reaches their goals, but it is good to know that the awareness is increasing. If the designers obtain more knowledge about ecological design, maybe they can afford to let a project take more time so the ecological approach can be applied. It would gain the sustainable development in the future.

Final conclusions

Public parks are the biggest contributor to the green infrastructure in Xi'an. The parks cover large areas, but are not connected to each other or to other elements of green infrastructure. Still the parks contain a lot of trees and other flowering species, beneficial for biodiversity. Bigger main roads also consist of a lot of greenery, where both trees, shrubs and ground cover are presented. There is also vegetation between the road lanes. A six-row avenue of trees is common in Xi'an. Perhaps it is possible to apply that type of greenery in most of the streets that are lacking of green infrastructure today.

Western influences, such as lawns and flowerbeds, are commonly seen in the green infrastructure of Xi'an. Such elements are common especially in green areas inside neighborhoods and in the front of historical monuments, campuses and governmental institutions. Hopefully, the proposal in this thesis will inspire stakeholders in China to adjust western influences to the Chinese culture and to local conditions and to start thinking in a more sustainable manner (especially considering maintenance). We also hope that there is time to go back to the roots of classical Chinese gardens with their respect of nature and culture.

Ecological approaches, such as rain gardens, bio swales, green roofs and vertical gardens (green walls) can all be applied in Xi'an to create sustainable green infrastructure, but lack of knowledge is a restricting factor. Professor Li Houhua (interview 2015) promoted green walls and green roofs ahead of rain gardens and bio swales because of lack of space between the buildings in the city. Rain gardens have recently been applied in a neighborhood in Xianyang City. According to Ignatieva³ biodiverse meadows are not suitable for the Chinese climate and are also something that one cannot find in classical Chinese gardens. Using sustainable material and native species, though, is a good start to achieve sustainable urban development, according to Dr. Qiu Ling (interview 2015).

The results of this master thesis indicated that modern Xi'an green infrastructure is only partly fulfilling ecosystem services. Our field and observational studies and studies of maps have showed that the green infrastructure in Xi'an is fragmented. As Doctor Qiu Ling stated: "the green infrastructure is sick at the moment, and by using ecological ways to make it sustainable and build a network we can make the cities healthier" (interview 2015). The creating of a sustainable green infrastructure plan in Xi'an is progressing, but so far the city expands without a concrete green infrastructure planning. The professors

interviewed have all come to the same conclusion that the green infrastructure not fulfill ecosystem services and that the air quality are getting worse.

Fortunately, China is aware of these problems and many sustainable projects are initiated and implemented, such as the Sponge Park in Xi'an. The interviews also showed that the green infrastructure is more important today than 20 years ago and, thus, very important for bigger cities. As Ignateiva et al. (2015) concluded, even small green areas are of great value for the physical and spiritual health of Chinese cities. We sincerely hope that the future will bring more valuable exchange between successful case studies of green areas from both Western and Eastern perspective.

Further research questions

While working with this thesis many interesting follow-up questions appeared during the research and the field study. Due to our limitations we could not include all the questions that appeared but we think they are both important and worth to look further into.

Results of this thesis show that green belts and green corridors have to be improved in the city. To make a more detailed design proposal for that kind of green infrastructure could be an interesting study. Also how to develop the existing street space into ecological green corridors is an interesting question.

From the intermediate scale proposal one of the design solutions was chosen to make a detailed small scale proposal in this thesis, but how could a small scale design proposal look like for the other types of ecological design solutions in the intermediate scale proposal?

Since the Chinese people seem very fond of Western influences with lawns and meadows and continues to include this type of design in their parks and other green spaces, there should be a way to adapt these principles into the Chinese culture, but how?

Professor Li mentioned in the interview that the people and the government should be more enlightened about their environment and it's changing, so further research required is how you could make the government more aware of the environmental conditions so they could have a better understanding of the importance in taking care of it?

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Li Houhua, Professor in Landscape Architecture, at Northwest A&F University

Ji Wenli, Professor in Landscape Architecture, at Northwest A&F University

Mr. YU Kanhua, City gardener and Urban planner in Xi'an

Mr. ZHOU Bin, Local Politician in Xi'an

Maps

Figure 2. *Xi'an City Planning Bureau*. (2007). Green space planning map. [online]. Xi'an. Available at: http://www.xaghj.gov.cn/ptl/def/def/index_915_6236_ci_trid_1008956.html [2015-02-27]

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APPENDIX 1

Observational guide

Date/time:
 Neighborhood:
 Site:
 Weather:
 Weekday/weekend:

| Activity | Total amount of people | Age | | | | Gender | | Comments |
|----------------------------|------------------------|------|-------|-------|-----|--------|--------|----------|
| | | 0-15 | 16-25 | 26-50 | 50+ | Male | Female | |
| NECESSARY ACTIVITIES | | | | | | | | |
| Walking | | | | | | | | |
| Walking the dog | | | | | | | | |
| Walking with baby stroller | | | | | | | | |
| Cycling | | | | | | | | |
| Driving | | | | | | | | |
| OPTIONAL ACTIVITIES | | | | | | | | |
| Exercising | | | | | | | | |
| Sitting | | | | | | | | |
| Resting | | | | | | | | |
| Standing | | | | | | | | |
| Play instrument | | | | | | | | |
| Reading | | | | | | | | |
| Meditating | | | | | | | | |
| Using cellphone/ computer | | | | | | | | |
| Working | | | | | | | | |
| SOCIAL ACTIVITIES | | | | | | | | |
| Dancing | | | | | | | | |
| Playing | | | | | | | | |
| Talking | | | | | | | | |
| Eating | | | | | | | | |
| Fest | | | | | | | | |

Inventory guide

Date/time:
 Neighborhood:
 Weather:
 Weekday/weekend:

| Conditions | Site 1 | Site 2 | Site 3 |
|--|--------|--------|--------|
| WEATHER Sun Sun/shadow Shadow from buildings Wind Breeze No wind | | | |
| SOUND Bird song Traffic Music Noise from construction Other: | | | |
| SMELLS Blossom Greenery Food Exhaust Other: | | | |
| CIRCULATION Pedestrian/20min Vehicle/20min | | | |

Other inventories:

- Map of pedestrian circulation
- Map of vehicle circulation
- Neighborhood description: structure of the neighborhood, number of buildings, shape/character of buildings, floors, material, color, roads, playground, carparks.
- Greenery description: plant material, character, structure of plantations, perceived amount of green/grey areas, conditions of trees, shrubs and lawns.
- Water features: Ponds, fountains.
- Compaction of soil on lawn areas because of overuse?
- Our own reflections:

APPENDIX 2

Questionnaire for Professors

1. What is your research about and for how long have you been working with this subject?
2. Are there many other persons working in the same field as you?
3. In your opinion what are the different functions of urban green infrastructure (green space planning)?
4. What is your vision, as a professor/researcher, of green infrastructure and sustainable green infrastructure? (Ecosystem services, Ecological design, Green links)
5. Do you think Xi'an's green infrastructure is fulfilling ecosystem services? In what way?

| Ecosystem services | Very much | Intermediate | Poor | Comments |
|---------------------------|-----------|--------------|------|----------|
| Biodiversity | | | | |
| Air quality | | | | |
| Recreational | | | | |
| Aesthetic | | | | |
| Other: | | | | |

6. What is your opinion about opportunities of implementing ecological design into common public green spaces? Do you have any examples?
7. What ecological approaches do you think can be applied to create sustainable green infrastructure in Xi'an?

| Ecological approaches | Yes | No | Comments |
|--------------------------------|-----|----|----------|
| Green roofs | | | |
| Vertical gardens (green walls) | | | |
| Swales | | | |
| Rain gardens | | | |
| Biodiversity lawns | | | |
| Pedestrian paths | | | |
| Bike lines | | | |
| Other: | | | |

8. Do you know of any good examples in Chinese cities where they have been successful with this type of concept?
9. Do you think the green infrastructure is more important today than 20 years ago? Why? What is the difference between the thinking 20 years ago and now?
10. Do you have anything else you would like to add?
11. Do you know any other person who can provide further information?
12. Is it okay to get back to you with further questions if we need?

Questionnaire for local Politician

1. Briefly describe your responsibility as a politician for the green infrastructure (green space planning) in Xi'an?
2. How familiar are you with the municipality policy in detail for green infrastructure in the city?
3. What is your vision of a sustainable city?
4. What are your visions/ideas concerning the green infrastructure in Xi'an?
5. Do you know any successful examples of sustainable green infrastructure projects in Chinese cities? And in Xi'an?
6. In your opinion what are the different functions of urban green infrastructure? For example recreational purposes, positive impact on air quality, habitat for flora and fauna etc.?
7. What is your view on the need for green infrastructure in Chinese cities? And Xi'an?
8. What is your opinion about opportunities of implementing ecological design into common public green spaces? Do you see any obstacles? What are the preconditions?
9. Do you think the green infrastructure is more important today than 20 years ago? What is the difference between the thinking 20 years ago and now?
10. Do you have anything else you would like to add?

11. Do you know any other person who can provide further information?

12. Is it okay to get back to you with further questions if we need?

Questionnaire for City gardener

1. Briefly describe your responsibility and tasks as a city gardener for the green infrastructure (green space planning) in Xi'an?

2. Are you familiar with the municipality policy for green infrastructure in the city?

3. In your opinion what are the different functions of urban green infrastructure? For example recreational purposes, positive impact on air quality, habitat for flora and fauna etc.?

4. Do you think Xi'an's green infrastructure is fulfilling ecosystem services? In what way?

| Ecosystem services | Very much | Intermediate | Poor | Comments |
|--------------------|-----------|--------------|------|----------|
| Biodiversity | | | | |
| Air quality | | | | |
| Recreational | | | | |
| Aesthetic | | | | |
| Other: | | | | |

5. What is your opinion about opportunities of implementing ecological design into common public green spaces? Do you have any examples?

6. What ecological approaches do you think can be applied to create sustainable green infrastructure in Xi'an?

| Ecological approaches | Yes | No | Comments |
|--------------------------------|-----|----|----------|
| Green roofs | | | |
| Vertical gardens (green walls) | | | |
| Swales | | | |
| Rain gardens | | | |
| Biodiversity lawns | | | |
| Pedestrian paths | | | |
| Bike lines | | | |
| Other: | | | |

7. Do you think the green infrastructure is more important today than 20 years ago? Why? What is the difference between the thinking 20 years ago and now?

8. What is your vision of a sustainable city?

9. What are your visions/ideas concerning the green infrastructure in Xi'an?

10. Do you have anything else you would like to add?

11. Is it okay to get back to you with further questions if we need?

APPENDIX 3

Interviews with Professors

Dr. QIU Ling

Dr. Ling is a landscape architecture planner. She has two doctor degrees, one in landscape ecology at Northwest A&F University and one at Alnarp, Sweden, in landscape planning and interdisciplinary methodology development of linking biodiversity in urban green spaces. Totally she has been in the industry for ten years. So far there are not many other people working in the same field as her, with the urban green spaces. It is more common with biologists and ecologists focusing on the rural areas than people focusing on the urban areas.

The green infrastructure is an important fundamental element Dr. Ling says, especially for developing counties. Because of the sacrifice of many natural resources we need to find a balance between the economic development and the natural conservation. You could say that the green infrastructure is sick at the moment, and by using ecological ways to make it sustainable and build a network, we can make the cities healthier. We should try to make the green infrastructure an ecosystem service function, a supporting function, a cultural function and a regulating function, Ling says. Her vision is to implement more greenery in the cities in the future, especially lawns, meadows, vertical gardens and roof gardens. The urban area is a limited place for developing green spaces, so we have to find a way to build a sustainable green infrastructure by using for example sustainable materials, native species and build green walls and green roofs.

Xi'an's green infrastructure is definitely not fulfilling the ecosystem services, she thinks. The air quality was better before, but now it is worse and the city needs development. The air pollution is very bad. The green infrastructure is fragmented, she continues, because the decision makers and developers don't have an overall picture of how the city should be planned. If they find an open space, they will

plan that specific area without regard to the surroundings. That is the reason there is no network of green infrastructure and not a very multifunctional green infrastructure in Xi'an, Dr. Ling says. The plastic trees that are used in urban spaces are a clear sign of the lack of greenery in the cities.

To implement ecological design in public green spaces would definitely be necessary and a smart way to develop the urban greenery, according to Dr. Ling. The social aspect is very important too, but one is not more important than the other, so combining these two aspects would be a good way to make the green infrastructure development successful. The first step to build green corridors or a green network in the city would be to collect basic data's about the different green spaces and value it from an ecological perspective, Dr. Ling says. Information like size, location, biological and ecological information, historical and esthetical information would be necessary data's. Virtual mapping is a good way to do it.

According to Dr. Ling, one of the best Chinese landscape architects is Kongjian Yu from Beijing, who runs the famous Chinese company Turenscape. He uses the ecological approach in his projects, for example in designs of wetlands. He also changes old factory into a vivid landscape in a sustainable way. He wants to let the nature free, not limit the nature by building manmade or concrete infrastructure. Outside Xi'an there is a wetland park named ChanBa Wetland Park that could be an interesting visit.

In a developing country like China they had to sacrifice the natural resources for the economic development in the country twenty years ago. Today the economic development is improved and the attention on focusing on the natural conservation is growing. The green infrastructure should be emphasized at present, but it should have been even twenty years ago, because now it seems like the nature is trying to

revenge us, by for example air pollution and flooding, she says. These consequences are because of the lack of green infrastructure and the loss of the natural ecosystem services.

Dr. Ling thinks green infrastructure is a quite new concept, it wasn't even recognized by experts twenty years ago. The different professions worked separately and the focus of green infrastructure was on the engineering.

Professor Li Houhua

Professor Li Houhua works at the Northwest A&F University in Yangling, just outside Xi'an. His main subject is the green infrastructure and now his focus is a research about metabolic engineering of flavonoid biosynthesis in apple by genetic transformation from maize. This research has been going on since 2004. They are about eight colleagues working in the same field at the university.

The green infrastructure is very important for the city, Professor Li says. The cars emit many gases that are dangerous for the people, for instance different sulfates and carbon dioxide. The gases also contribute to the greenhouse effect which is dangerous for our Earth. Therefore, the most important function the green infrastructure has in the cities, is to decrease the dangerous gases, Professor Li states. His vision is to enlighten the people and the government so they will be aware of the damage of the ecosystem the man is causing, and for somehow prevent it. His vision is also to increase the urban green infrastructure in favor for the ecosystem.

At present the green infrastructure in Xi'an is not fulfilling ecosystem services. Professor Li means that the buildings and the cars are taking too much space and there are no room left for the vegetation. According to Professor Li the biodiversity in Xi'an is poor and the air quality is even worse. But the green infrastructure does have a

Smog covers the city of Xi'an



recreational and an aesthetic value.

Professor Li thinks there are great opportunities to increase the urban green infrastructure and implement ecological designs in Xi'an. But the way it should be done is with green walls and green roofs because of the lack of space between the buildings. But if there are areas with enough space for ecological design elements, the swales, biodiversity lawns and rain gardens could also be applied. Pedestrian paths and bike lines though, could be hard to develop in Xi'an because there is not enough space. In a city called Chengdu here in China, green roof gardens has been a successful concept.

Green infrastructure is more important today than it was twenty years ago, according to Professor Li. We have noticed that the climate is changing because of the human activities and that is not good for neither the man nor the Earth.

Professor Ji Wenli

Professor Ji Wenli works at the Northwest A&F University in Yangling. Her major is flowers, especially peonies which she has been working with for two years. There are about six people in the university that is working with this subject. She also studies different types of forest plants to see if they can be used in urban environments. This research has been going on for three years and about three persons are involved from the university.

Recreation, ecology and economy are the basic values of the green infrastructure according to Professor Ji. The green infrastructure in Xi'an is not enough, it has to be improved and require more green spaces. If the green structure in the city can be improved, the ecosystem services can be that as well. Now it is not very good. It cannot be used today, she means.

There are designers working with a plan for the green infrastructure in the city but it is not finished yet. The city's green infrastructure does not fulfill the ecosystem services, she declares. She recently visited a design office to discuss the development of the city's green spaces. They want to have a cooperation for making plans for the green infrastructure in Xi'an.

Ecological storm water managements for the city are under construction. Sponge Park is an example of a place where the storm water is stored for the city. This park is a model how to build this kind of ecological design. This is the first project in the Shaanxi province that has been made.

Rain gardens do not exist in Xi'an now, but it is something to strive for to apply in the city. There are some ecological projects going on but they are not finished. The designers want to implement more ecological design, but they cannot fulfill the design because they don't have enough knowledge and very short of time in the projects.

There are no green roofs in Xi'an, but you can find it in Chengdu. As well as bio swales, they cannot be found in the city. She thinks that vertical gardens is applicable in the city, they are simple to apply. Biodiversity meadows on the other hand, there are no intentions to build that.

Pedestrian paths can be more sustainable if they are built as steppingstone paths. More rainwater can be infiltrated between the stones. Bike lines are not very common in Xi'an. She mentions further that Baoji is a city near Yangling, which is built with a more ecological approach. It has more green spaces and more plants for biodiversity richness.

The green infrastructure is more important today than twenty years

ago because the smog is worse. The green infrastructure is "destroyed" and people should wear a mask when they are outdoors to protect themselves from the bad air conditions. It has become more important to care about the green infrastructure because of increasing awareness of bad air quality in the city. They will make an effort to design and build with a more ecological approach, she states.

Interview with City gardener

Mr. YU Kanhua

Mr. Yu works in Xi'an, both as a city gardener and as an urban planner. He has worked in this position for fifteen years. The work includes project planning from the city scale to the local scale. He is therefore both into practice, design and construction of green space.

The municipality policy includes three updated green space planning policies; 2002, 2006 and 2008. There are no modifications of the policies after 2008. They follow the policy in the daily work but not all the time to the letter, because they have to adjust the policy to the present conditions due to it is not very up to date. The adjustments are based on specific projects and the location, geographic condition, climate condition and local municipality requirements.

From his perspective as a city gardener and a city planner, he thinks functions of green infrastructure include recreational purposes, improve air condition, biodiversity, and ecological habitats and so on. From the government perspective they need to consider commercial profits, because the green space is also a part of the land recourses in the city, which is a founding resource.

He absolutely thinks the green infrastructure in Xi'an provides better air quality, biodiversity, recreational and aesthetical values to the

city. There are a lot of people using the green spaces for exercise and recreation.

His opinion of ecological design is low technology dependent and the natural system perspective. To apply the ecological design the local conditions should be defined, for example the local history and culture. The Qujiang district is an example where it has been implementations of ecological designs.

He think, based on current conditions in Xi'an, the green roofs and the vertical gardens could be possible to apply in the city to further create sustainable green infrastructure. Swales and rain gardens for example could be difficult to apply due to the top-down approach of the urban planning in China.

There were not very much green spaces in the cities before, but nowadays there are standards for the amount of green spaces in a city, it should be at least 7-8 percent green areas. Green spaces are more important today because it will improve the environmental conditions which could lead to more investments.

The most important thing about a sustainable city is to have a resilient city that could heal itself. His vision is that the green infrastructure will be improved in Xi'an. The city gardeners and the city planners should introduce more modern thinking and technologies in their daily work, for example GIS.

Interview with local Politician

Mr ZHOU Bin

Mr Zhou works as a local politician in Xi'an. His responsibilities include the green structure in the city planning and the design and

maintenance of it as well.

The municipality policy is to make Xi'an a forest city, now it is a garden city, meaning they seek to make Xi'an a greener city in the future. They are planning to build 10-20 new green areas in the city every year. The goal is that all citizens should have access to a green area within fifty meters from their home. 40-50 percent of green areas are a standard for a garden city, and in new projects the amount should be at least 40 percent to be approved by the government.

His understanding of a sustainable city is to educate more landscape architects to have more people in the business to increase the greenery. Their vision is to become a forest city and to reach that they have to increase the greenery inside the city wall. The most important issue is how to connect the green existing areas with each other. But there are a lot of old buildings so they have to implement green areas in another way than on the ground so they don't have to tear down the houses, for example by green roofs and green walls.

In Qujiang new district they have included the green areas in the planning process. This area has been a model for green infrastructure planning in other cities as well. They have more space between the buildings to make room for the green areas. He also mentions that they have been successful with this concept, both the improvement of green infrastructure and the ecological design, in ChanBa district in the north part of Xi'an.

He said that the cities by the coast in China, particular in the south, green infrastructure are more developed. But he thinks that all cities in China needs more green spaces.

The view of green infrastructure is not the same in China as in the western world. He says that the green infrastructure is related to the

landscape greenery and has a big aesthetic value; it is like accessories to the city. The main function when building new districts is to make profit, he means.

The politicians are paying more attention to the green infrastructure nowadays because of the environmental problems. The general public is also aware of the need for more green areas and the government listens to their views.

He thinks the implementation of ecological design already is improved because of the requirement from the government. They use more different species and get inspiration from other cities. They also have more money to maintain the green areas today.

The opportunities to implement green roofs and vertical gardens are good, but there are also difficulties, for example how to connect them as a landscape.

He thinks the green infrastructure is more important today than 20 years ago, and it has been improved because of the use of more species. The mayor is also paying more attention to the green areas. Before they thought more about the economic development in the cities and built more grey infrastructure.

